Quizix

5000 Series Pump System User's Manual

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CHAPTER 1 General Overview 1-1
1.1 Introduction 1-1
1.2 Primary Components 1-2
1.2.1 C–5000 Pump Cylinder 1-3
1.2.2 CMD-5000 Dual Controller Driver 1-4
1.2.3 PC–Compatible Computer and PumpWorks Software 1-4
1.2.4 Valves, Transducers and Plumbing 1-4
1.2.5 Support Stand 1-4

CHAPTER 2 System Setup 2-1
2.1 Unpacking the System 2-1
2.2 Installing the Pistons 2-1
2.3 Setting Up a Stand–Mounted System 2-6
2.4 Setting Up a High Temperature System: Oven Installation 2-8
2.4.1 Pump Cylinders 2-8
2.4.2 CMD–5000 Dual Controller Driver 2-9
2.4.3 Transducers 2-9
2.4.4 Valves 2-9
2.4.5 Cables 2-9
2.5 Power Considerations 2-10
2.6 Requirements for Air Supply 2-11

CHAPTER 3 System Checkout 3-1
3.1 Verification of All Cable and Plumbing Connections 3-1
3.1.1 Connection Checklist 3-2
3.2 Valve Check 3-3
3.3 Pump Cylinder Check 3-3
3.4 Filling the Pump System with Liquid 3-4
3.5 Pressure Transducer Check 3-5

CHAPTER 4 PUMP OPERATING BASICS 4-1
4.1 Introduction to Using PumpWorks 4-1
4.2 PumpWorks Main Window 4-1
4.2.1 Windows 4-2
4.2.2 Title Bar 4-2
4.2.3 Menu Bar 4-3
4.2.4 Pump Data & Controls Window 4-3
4.2.5 Status Bar 4-3
4.2.6 Dialog Boxes 4-4
4.3 Pump Data & Controls Window 4-4
4.3.1 Pump Name 4-4
4.3.2 Cylinder Number 4-4
4.3.3 Piston Position 4-4
4.3.4 Motion Status 4-5
4.3.5 Start/Stop Pumps 4-7

4.3.5.1 Starting Pump Cylinders 4-7
4.3.5.2 Starting Pump Cylinders in Independent Operating Modes 4-7
4.3.5.3 Starting Pump Cylinders in Paired Operating Modes 4-8
4.3.5.4 Stopping Pump Cylinders..... 4-8
4.3.6 Current Pressure..... 4-9
4.3.7 Set Pressure..... 4-9
4.3.7.1 Changing a Set Pressure..... 4-9
4.3.7.2 Changing Multiple Set Pressures 4-9
4.3.8 Current Flow Rate..... 4-9
4.3.9 Set Flow Rate..... 4-10
4.3.9.1 Changing a Set Flow Rate..... 4-10
4.3.9.2 Changing Multiple Set Flow Rates 4-10
4.3.10 Cylinder Volume..... 4-10
4.3.11 Cumulative Volume..... 4-10
4.3.12 Operating Modes..... 4-10
4.3.12.1 Pump Cylinder Configuration 4-10
4.3.12.2 Pump Cylinder Operation Mode 4-11
4.3.12.3 Fluid Flow Direction 4-11
4.3.12.4 Choosing an Operating Mode 4-11
4.3.12.5 Independent Cylinder Configuration..... 4-16
4.3.12.6 Paired Cylinder Configuration 4-17
4.3.12.7 Mixed Configurations and Mixed Modes 4-17
4.3.13 Cylinder Direction (Direction of Piston Movement) 4-18
4.3.14 Fill and Deliver Valves 4-18
4.4 Set Safety Pressure 4-19
4.5 Errors Present 4-19

CHAPTER 5 Safety Features 5-1
5.1 Cable Connections Sensing 5-1
5.2 Cable Labeling 5-1
5.3 Overpressure Protection Safety Features 5-1
5.3.1 Digital Overpressure (Safety Pressure Setting) 5-1
5.3.2 Digital Underpressure 5-2
5.3.3 Analog Overpressure..... 5-2
5.3.4 Safety Rupture Disk..... 5-2
5.3.4.1 Safety Rupture Disk Holder..... 5-4
5.3.4.2 Safety Rupture Disk Holder..... 5-4
5.3.4.3 All C-5000 Pump Cylinder Models 5-4
5.4 Emergency Stop Capability 5-5

CHAPTER 6 CMD-5000 Dual Controller Driver 6-1
6.1 The Pump Controller Subcomponent 6-1
6.2 Motor Driver Subcomponent 6-2
6.3 On/Off Switch, Power Cord, and Fuse Holder 6-2

6.4 Cable Connections 6-3
6.4.1 Sensor Cable 6-3
6.4.2 Motor Cable 6-3
6.4.3 Transducer and Valve Cable 6-3
6.4.4 Data Link Cable 6-3
6.4.5 Front Panel Cable 6-4
6.4.6 User Interface Cable 6-4
6.4.7 AC Power Cord Receptacle 6-4
6.4.8 RS-232 Cable 6-4
6.5 Pump Number (Two-Digit Display) 6-4
6.6 Serial Expander/Isolator 6-6
6.7 Pump Controller Software 6-7

CHAPTER 7 Pump Cylinder 7-1
7.1 Quizix C-5000 Pump Cylinder 7-1
7.2 Important Operating Notes 7-3
7.3 Primary Mechanical Subcomponents of the Pump Cylinder 7-4
7.3.1 Stepper Motor 7-4
7.3.2 Harmonic Drive 7-4
7.3.3 Ball Screw and Ball Nut 7-4
7.3.4 Ball Nut Assembly 7-4
7.3.5 Piston and Cylinder Barrel 7-4
7.3.6 Bearings 7-5
7.3.7 Side Rails and Rollers 7-5
7.4 Cylinder Barrel and Seal Assembly 7-5
7.5 Pump Cylinder Sensor Board 7-6
7.6 Pump Cylinder Base Plate 7-7
7.7 Hastelloy Option for Corrosive Fluids 7-7
7.8 Pump Cylinder High Temperature Option 7-7
7.9 Pump Cylinders with Optional Wash Ring 7-9

CHAPTER 8 Valves, Transducers and Plumbing 8-1
8.1 Valves 8-1
8.2 Pilot Solenoids 8-2
8.3 Air Supply 8-3
8.4 Pressure Transducers 8-4
8.5 Fluid Plumbing 8-5
8.5.1 User–Supplied Tubing 8-5
8.5.2 Stand–Supplied Tubing 8-5
8.6 Safety Rupture Disks 8-7
8.7 Hastelloy Option for Corrosive Fluids 8-8
8.8 High Temperature Option 8-8
8.8.1 Transducers 8-8
8.8.2 Valves and Pilot Solenoids 8-8

CHAPTER 9 System Cables 9-1
9.1 Motor Cable 9-1
9.2 Sensor Cable 9-1
9.3 Transducer and Valve Cable 9-1
9.4 Data Link Cable 9-2
9.5 RS–232 Cable 9-2
9.6 AC Power Cables 9-2
9.7 User Interface Cable (Optional) 9-3
9.8 Front Panel Cable (Optional) 9-3
9.9 Cable Extensions 9-3

CHAPTER 10 System Power 10-1
10.1 Basic Power Requirements 10-1
10.2 Using Uninterruptable Power Supplies 10-1
10.3 Changing the Voltage Setting 10-2
10.4 Replacing a Fuse 10-3

CHAPTER 11 Maintenance 11-1
11.1 Special Tools and Spare Parts Kit 11-1
11.2 Changing the Cylinder Barrel Seals 11-3
11.2.1 Removing the Cylinder Barrel 11-3
11.2.2 Changing the Seals 11-4
11.2.2.1 Cup-Type and T-Type Seals 11-4
11.2.2.2 Seal Removal Procedure for All Seals 11-5
11.2.2.3 Seal Insertion Procedure for Cup–Type Seals 11-6
11.2.2.4 Seal Insertion Procedure for T–Type Seals 11-7
11.2.3 Inspecting, Removing, Cleaning, and Re–Installing a Piston 11-8
11.2.3.1 Inspecting and Cleaning a Piston 11-8
11.2.3.2 Re–installing the Piston 11-9
11.2.4 Replacing the Cylinder Barrel 11-9
11.3 Maintaining the Pump Cylinder 11-9
11.3.1 Replacing the Cam Rollers 11-9
11.3.2 Re–Greasing the Ball Screw 11-11
11.3.3 Re–Greasing the Harmonic Drive Bearing 11-13
11.4 Cooling Fan Maintenance 11-17
11.4.1 High Temperature Systems 11-17
11.4.2 CMD-5000 Fan 11-18
11.5 Replacing the Safety Rupture Disk 11-18
11.6 Calibrating the Pressure Transducers 11-20
11.6.1 What is a Pressure Transducer? 11-21
11.6.2 Methods of Calibrating the Pump System 11-21
11.6.2.1 Calibrated Gauge Method 11-22
11.6.2.2 Calibrated Pressure Source Method 11-24
11.7 Valve Maintenance 11-25

CHAPTER 12 Troubleshooting 12-1
12.1 Troubleshooting Basics 12-1
12.2 PumpWorks Error Messages 12-2
12.2.1 Immediate Errors 12-3
12.2.2 Logged Errors 12-3
12.2.2.1 Soft Limit Warning 12-3
12.2.2.2 Communication Errors 12-3
12.3 CMD-5000 Two Digit Display Error Messages 12-5
12.3.1 The Two Digit Display Does Not Light 12-6
12.3.2 The Two Digit Display Does Not Complete Its Initial Check 12-6
12.3.2.1 Pump Controller Diagnostics 12-6
12.3.2.2 Pump Controller Software Initialization 12-8
12.3.3 Two Digit Display Error Code 12-8
12.4 Other Pump Troubleshooting Situations 12-10
12.4.1 Air Supply Problems 12-10
12.4.1.1 No “Air Escaping” Sound When Valves are Opened and Closed 12-10
12.4.1.2 Constant “Air Escaping” Sound 12-11
12.4.2 Fan Does Not Run 12-11
12.4.3 Fluid Leaks 12-11
12.4.3.1 Leakage Basics 12-11
12.4.3.2 Leak Testing 12-12
12.4.3.3 Does Your Pump Have a Fluid Leak? 12-12
12.4.3.4 Finding Your Leak 12-13
12.4.4 No Fluid Is Being Delivered 12-13
12.4.5 Piston Motion Errors 12-14
12.4.5.1 Motor Running, No Piston Movement Detected Error 12-14
12.4.5.2 Motor Stall Error 12-15
12.4.5.3 Piston Moves, But Does Not Complete Its Stroke 12-15
12.4.6 Pressure Problems 12-15
12.4.6.1 Pressure Transducer Errors 12-15
12.4.6.2 Pressure Does Not Increase Within 30 Seconds 12-16
12.4.6.3 Pressure Overshoots Setting in Constant Pressure Mode 12-16
12.4.6.4 Pressure Is Not Constant in Constant Pressure Mode 12-16
12.4.7 Valve Problems 12-16
12.4.7.1 Valve Cable Connection Check 12-17
12.4.7.2 Checking Your Air Supply 12-17
12.4.7.3 Air Supply Requirements 12-17
12.4.7.4 Checking Your Air Supply Connection 12-17
12.4.7.5 Pilot Solenoid Check 12-17
12.4.7.6 Clogged (Obstructed) Valve 12-17
12.4.7.7 Valve Leaks Fluid When Closed 12-18
12.5 Software Updates 12-18

GLOSSARY G-1

INDEX Index-1

1 GENERAL OVERVIEW

This manual, the Quizix 5000 Series Pump System User's Manual, provides operating and maintenance instructions for the "hardware" of all Quizix SP-5000 pump systems. A separate manual, the PumpWorks User's Manual, discusses the software which operates all Quizix pump systems.

This chapter provides an introduction to the Quizix 5000 Series Pump System and includes an overview of its components.

1.1 Introduction

The Quizix 5000 Series Pump System provides continuous, pulse–free fluid flow for use in core analysis and related research. Key features of the system include the following:

- It is designed for pumping fluids at high pressure and provides precise pressure control.
- Sophisticated electronics provide highly accurate fluid flow rates and volume measurement.
- The system works well with water, oil, or brine. Fluid-wetted parts are available in Hastelloy (C-276) for users pumping highly corrosive fluids.
- The pump system is operated using Quizix PumpWorks© Software, which runs on a PC-compatible computer (486 or Pentium® based, 66 mhz minimum), using Windows 95, Windows 98, Windows NT, Windows 2000, or Windows XP operating system. The software provides the user with complete control over all operating parameters.
- The pump system can be operated in many different operating modes, including Constant Rate, Constant Pressure, and Constant Delta Pressure. The pump system can also operate in both directions; it can either deliver or receive fluid.
- Pumpworks permits system–level integration of the user's entire experiment, by allowing the user to add additional valves, digital signals or analog sensors (such as transducers or temperature readings) and accessing them with PumpWorks.
- PumpWorks allows the user to record all operating data in a data log on the computer and to export data using a host link.
- A high temperature (160°C) option is available which allows the user to heat the entire pump cylinder for reservoir condition experiments.

The basic building block of the 5000 Series Pump System is the C-5000 pump cylinder. Quizix manufactures six different models of C-5000 pump cylinders (refer to Table 1-1). They provide different maximum flow rate and pressure specifications. In general, the higher the maximum pressure specification, the lower the maximum flow rate specification. The two "L" models are designed for applications where extremely low flow rates are required.

For comparison purposes, Table 1-2 shows the three pump cylinder models available in the 6000 Series. Users who require higher flow rates or fluid volumes than the 5000 Series provides can use a 6000 Series pump cylinder.

Table 1-1 The 5000 Series Pump Cylinders				
Model	**Maximum Pressure**	**Maximum Flow Rate**	**Piston Stroke Volume**	**Piston Diameter**
C–5000-2.5K	2,500 psi	60 ml per minute	37 ml	1.00 inch
C–5000-5K	5,000 psi	30 ml per minute	21 ml	.750 inch
C–5000-L-7.5K	7,500 psi	3.75 ml per minute	21 ml	.750 inch
C–5000-10K	10,000 psi	15 ml per minute	9.3 ml	.500 inch
C–5000-L-10K	10,000 psi	2.0 ml per minute	9.3 ml	.500 inch
C–5000-20K	20,000 psi	7.5 ml per minute	5.2 ml	.375 inch

Table 1-2 The 6000 Series Pump Cylinders				
Model	**Maximum Pressure**	**Maximum Flow Rate**	**Piston Stroke Volume**	**Piston Diameter**
C–6000-5K	5,000 psi	400 ml per minute	550 ml	2.00 inch
C–6000–10K	10,000 psi	200 ml per minute	275 ml	1.41 inch
C–6000–20K	20,000 psi	100 ml per minute	135 ml	1.00 inch

1.2 Primary Components

The Quizix 5000 Series Pump System is designed as a modular component system. Pump systems can include from one to eight C-5000 pump cylinders, using any of the pump cylinder models shown in Table 1-1 above. Two pump cylinders are necessary for continuous flow of a single fluid. A standard SP–5200 two–cylinder pump system and standard SP–5400 four–cylinder pump system typically include the following components:

Table 1-3 Primary Components	
SP-5200 2–Cylinder System	**SP-5400 4–Cylinder System**
2 pump cylinders (choice of models)	4 pump cylinders (choice of models)
2 CV–310 valves	4 CV–310 valves
2 pressure transducers	4 pressure transducers
1 CMD-5000 Dual Controller Driver	2 CMD-5000 Dual Controller Drivers
1 two–cylinder support stand	1 four–cylinder support stand
Plumbing and cables	Plumbing and cables
1 PC–compatible computer	1 PC–compatible computer
Quizix PumpWorks software	Quizix PumpWorks software

The 5000 Series two–cylinder pump system (known as an SP-5200) is shown in Figure 1-1 below. A computer can be supplied by the user or purchased from Quizix as part of the pump system.

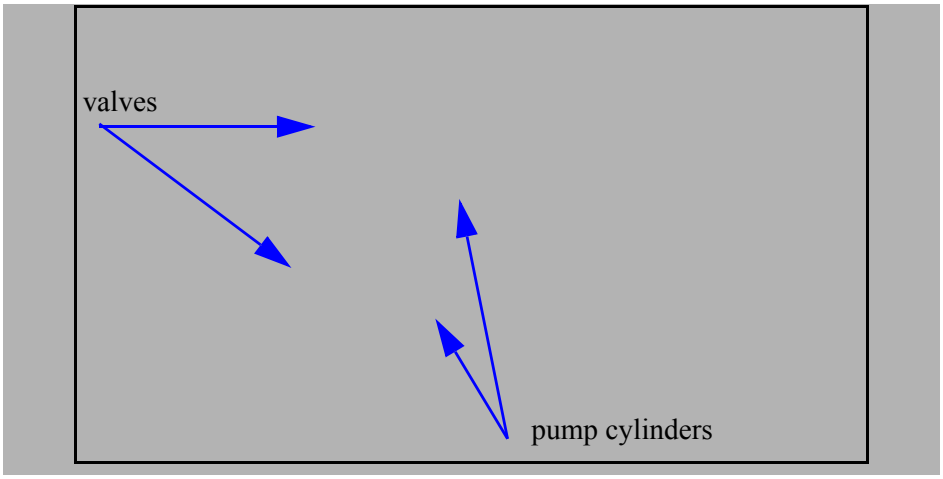

Figure 1-1 Stand Mounted SP-5200 Pump System

Quizix components can also be configured as a closed loop, recirculating system to obtain Steady–State Relative Permeability measurements. Recirculating systems can be set up for one, two, or three fluids, and can maintain a pulse-free constant flow rate of one or more fluids through a sample while maintaining a constant pressure at the outlet of the sample. This type of system requires an additional pump cylinder and specialized software.

NOTE ON NOMENCLATURE: The terms “pump cylinder” and “cylinder” are used interchangeably throughout this manual, and refer to the entire mechanical component used to pump fluid as shown and labeled in the picture above. Pump cylinder part numbers begin with a “C”. For example, C-5000-10K is a 5000 Series pump cylinder with a maximum pressure rating of 10,000 psi.

The term “pump system” refers to one or more pump cylinders **together with** one or more pump controllers, valves, transducers, plumbing and PumpWorks software. The part number for an entire pump system begins with “SP”. For example an SP-5200-10K pump system includes two C-5000-10K cylinders. The number of pump cylinders in a system is given by the number following the “5”.

In a pump system with two or more pump cylinders, the cylinders in a pair are typically labeled “A” and “B”. For example, an SP-5400 would include four pump cylinders labeled 1A, 1B, 2A, and 2B. Within PumpWorks, two pump cylinders working together as a pair are referred to as a “pump”. For example, pump 1 consists of pump cylinders 1A and 1B.

All 5000 Series Pump Systems include the following components:

1.2.1 C–5000 Pump Cylinder

The pump cylinder is the basic building block of the system. It is the component that performs the actual pumping. A system can include any number of pump cylinders, from one to eight,

depending on the type of experiments the user plans to conduct. The user also chooses which of the six available C-5000 models would be best suited to their application. The most popular pump cylinder model is the C-5000-10K, which has a maximum pressure rating of 10,000 psi and a maximum flow rate of 15 ml/minute.

Two pump cylinders are required to provide continuous flow of one fluid. Working as a pair, one pump cylinder delivers fluid while the other pump cylinder fills with fluid, pre–pressurizes, and waits for its turn to deliver fluid. At the end of one pump stroke, the two pump cylinders switch and the pump cylinder that was delivering fluid now re-fills, pre-pressurizes, and waits for its turn to deliver fluid again, while the pump cylinder that was receiving fluid, now delivers it.

1.2.2 CMD-5000 Dual Controller Driver

The pump controller is the controlling unit for the entire pump system. It coordinates the operation of all the other pump components and operates the system according to the settings made by the user within PumpWorks software. The CMD-5000 Dual Controller Driver includes both:

- The pump controller, which is the electronic “brains” of the entire system, and
- The motor driver, which drives the stepper motors which are part of the pump cylinders.

The part number CMD-5000 stands for **C**ontroller **M**otor **D**river for the 5000 Series Pump Systems. The CMD-5000 Dual Controller Driver can operate two C-5000 pump cylinders. If your system includes three or four pump cylinders, you will need two CMD-5000 units. If your system includes five or six pump cylinders, you will need three CMD-5000 units.

1.2.3 PC–Compatible Computer and PumpWorks Software

A pump system includes Quizix PumpWorks Software, which runs on a PC–compatible computer under the Windows operating system. Quizix can provide a computer with the pump system, if desired.

PumpWorks is menu–driven and easy to use. PumpWorks allows the user to set all operating parameters, such as fluid flow rate or pressure. The software also provides the user with full system status information at all times. Data logging capabilities are available, allowing the user to automate data collection. Many other useful features are also included and described in the PumpWorks User’s Manual.

1.2.4 Valves, Transducers and Plumbing

For each pump cylinder, the system includes one air–actuated three–way valve, two valve solenoids, and one pressure transducer. All necessary plumbing (fluid tubing and fittings) and cables are also included.

1.2.5 Support Stand

A support stand is available on which all components for an ambient temperature 5000 Series Pump System can be mounted. The stand makes the system extremely compact and facilitates installation and operation. Two stand sizes are available: a SP-5200 stand which holds two pump cylinders (Refer to Figure 1-1) and a SP-5400 stand which holds four pump cylinders.

A high temperature stand that supports only the pump cylinders (but none of the other system components) is generally used with high temperature pump systems that are installed inside ovens. The high temperature stand, which holds two C-5000 pump cylinders, is shown in Figure 1-2. In high temperature systems, the CMD-5000 Dual Controller Driver, the pilot solenoids for the valves, and the pressure transducers must be placed outside the oven.

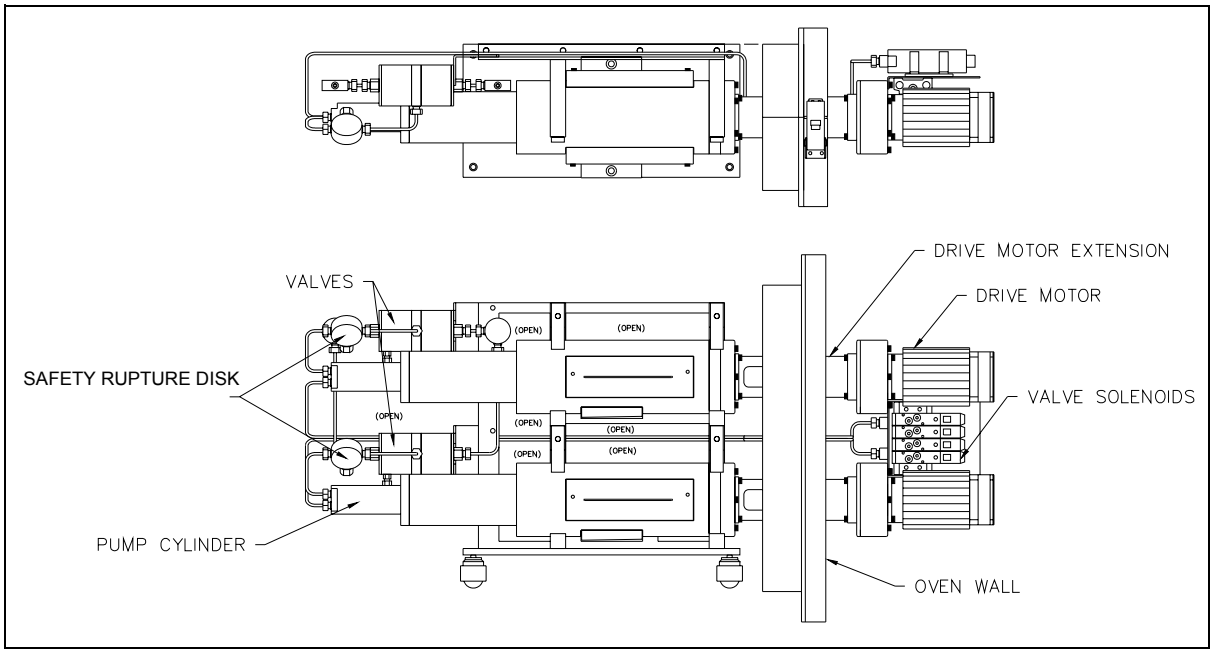

Figure 1-2 High Temperature Stand for the 5000 Series Pump Cylinders

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2 SYSTEM SETUP

This chapter provides the information necessary to set up a Quizix 5000 Series Pump System or change a system's setup, which includes the following:

- Unpacking the system, Section 2.1
- Installing the pistons, Section 2.2
- Setting up a system mounted on a support stand, Section 2.3
- Setting up a system installed in an oven, Section 2.4
- Power needs and considerations, Section 2.5
- Requirements for an air supply, Section 2.6

For more information about installing and using PumpWorks software, see the PumpWorks User's Manual.

2.1 Unpacking the System

Inspect the boxes for shipping damage. A component may have been damaged even if the box has only slight damage. It is the customer's responsibility to notify the shipping company immediately of any damage.

To open the pump cylinder boxes, which are long, low crates, do the following:

1. Remove the screws on top of the box and remove the lid.
2. Two screws, one on either side of the pump cylinder, hold the pump base in the shipping crate. Remove the two screws and lift the pump out of the shipping crate.
3. Remove the protective plastic shipping wrap from the pump cylinder and inspect for any shipping damage or loose parts.

   If you ordered a system mounted on a support stand, the remaining components are packed in the stand box. To unpack these components, do the following:

4. Remove the four lag bolts on the bottom of the box. There are two bolts on each end of the box. The stand assembly is mounted on the bottom of the shipping box.
5. Carefully lift the box straight up and high enough to clear the stand assembly. The stand is held onto the base of the shipping box by four clamps (two on each side) at the base of the stand.
6. Inspect for shipping damage. Remove the manual and unpack the tool kit.

2.2 Installing the Pistons

Due to previous experience with pistons being broken during shipment, the pistons of your 5000 Series pump cylinders are not installed in their cylinders for shipment. The pistons are packed separately and must be installed before the pump cylinders can pump fluid.

This section describes how to install the pistons into the pump cylinders. A more detailed description of this procedure is included in Chapter 11. The piston, which is made of silicon carbide, is extremely corrosion and scratch resistant, but is also brittle and may break if dropped.

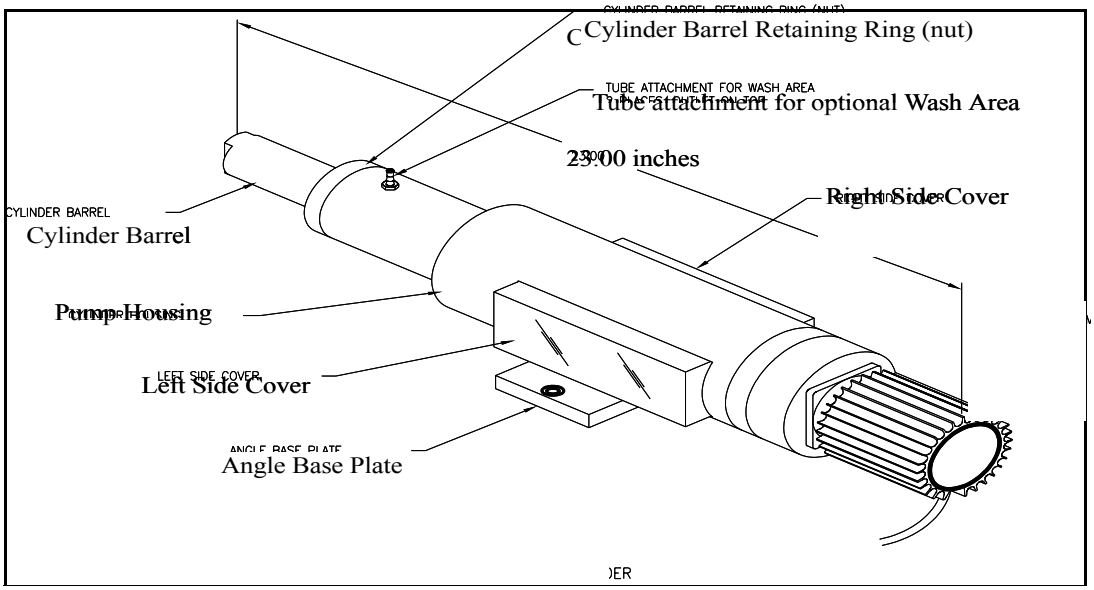

Figure 2-1 C-5000 Ambient Temperature Pump Cylinder

Required Tools: Face spanner wrench and 27 mm socket extension tool. Refer to Figure 11-1 on Page 11-1 for a photograph of these tools.

1. Remove the cylinder barrel retaining ring using the face spanner wrench supplied in the tool kit.
2. Unscrew the retaining ring, remove it, and pull the cylinder barrel straight out.
3. Unpack the piston, wipe it clean and place it into the 27 mm socket extension tool.
4. Install the piston into the end of the cylinder housing by inserting the piston and socket tool into the housing, and screwing it into the piston holder.
5. Tighten the piston with moderate force. Use a screwdriver and place it into the holes in the socket extension to do this.
6. Remove the front SpeedBite plug protectors and the rear dust protection plug.
7. Lubricate the end of the piston to ease installation through the main seal in the cylinder barrel.
8. Next, replace the cylinder barrel. Holding the cylinder barrel straight in front of the piston, insert the barrel onto the piston and push it straight into the cylinder housing until it is fully seated. Be sure that the speedbite tubing ports are oriented vertically above one another.
9. Replace the cylinder barrel retaining ring and tighten it securely with the face spanner wrench. Ensure that the ring is fully tightened.

This completes the piston installation. Repeat this procedure for each pump cylinder.

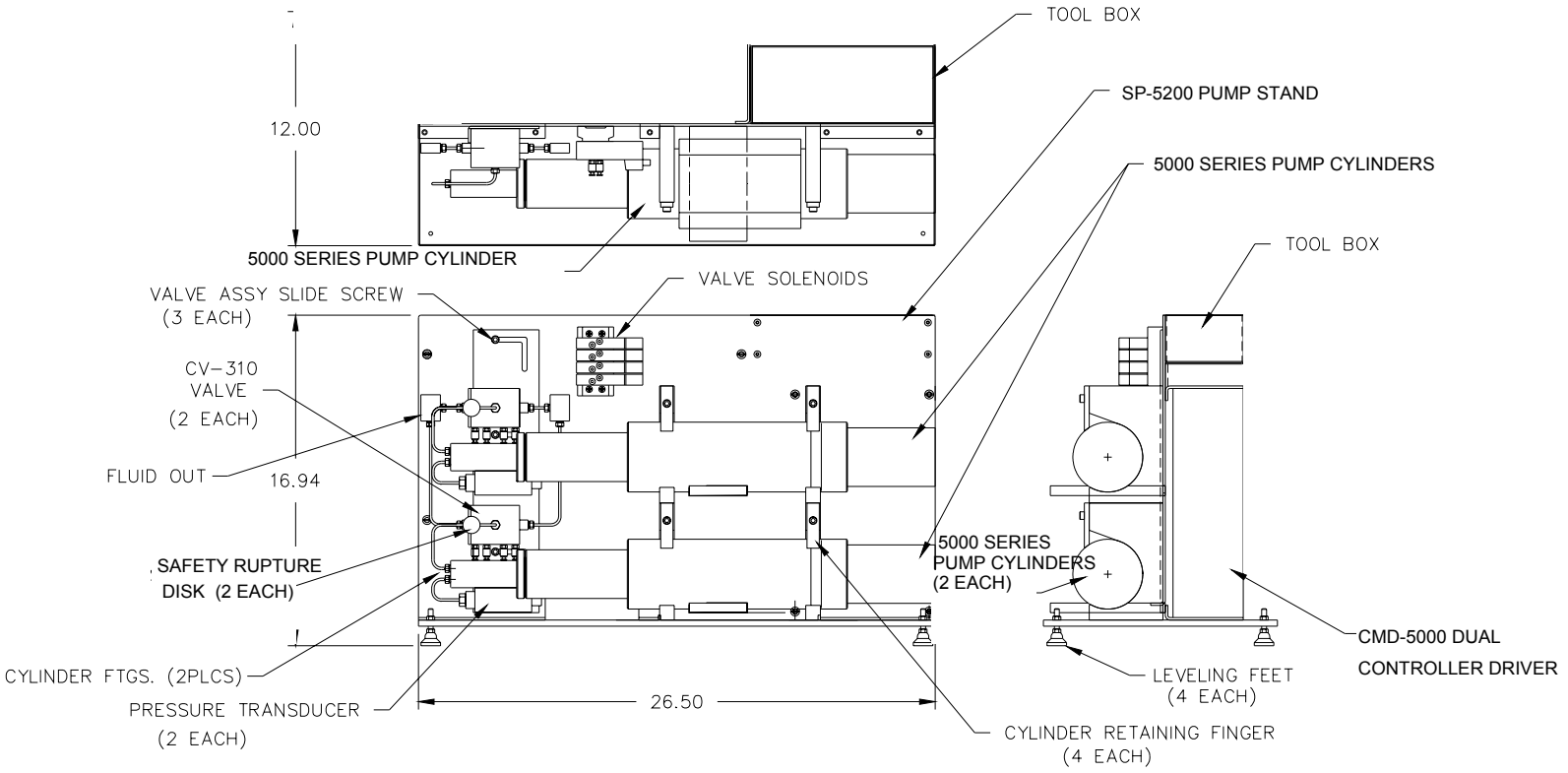

Figure 2-2 Stand–Mounted SP–5200

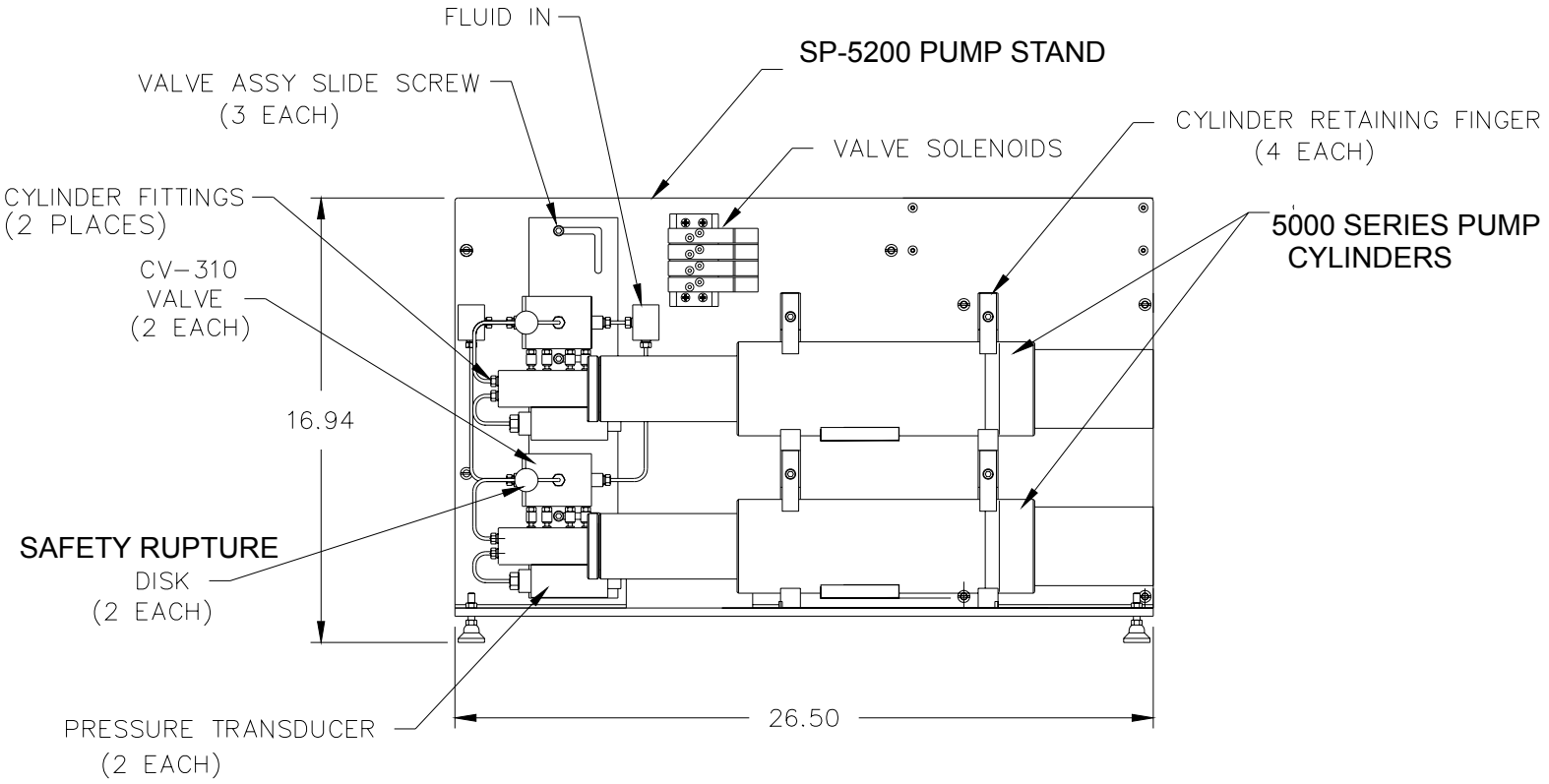

Figure 2-3 Expanded Front View of a Stand–Mounted SP–5200

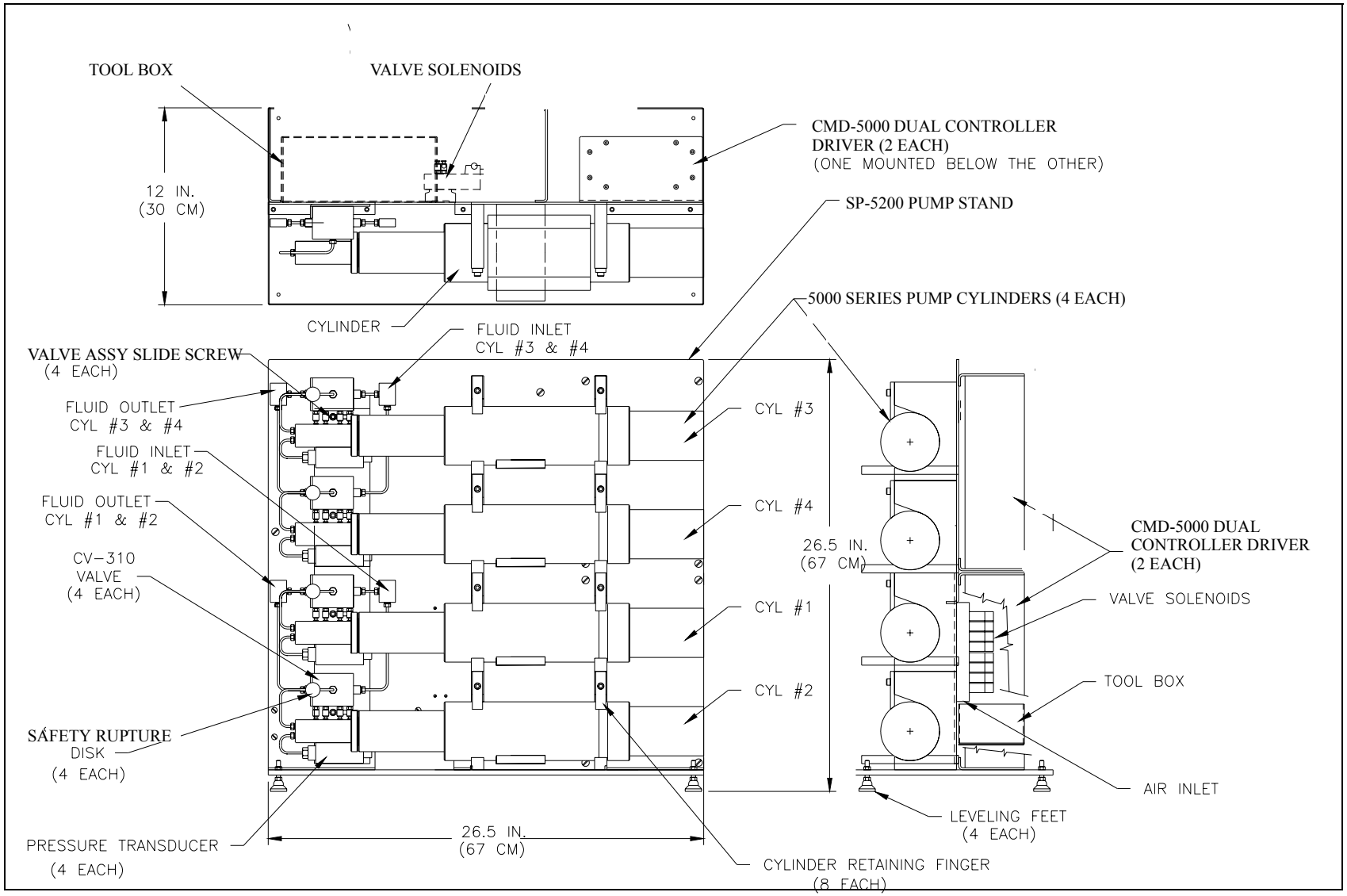

Figure 2-4 Stand–Mounted SP–5400 System

2.3 Setting Up a Stand–Mounted System

This section describes how to set up a stand–mounted system. Schematics for a stand–mounted SP-5200 two–cylinder system and SP-5400 four–cylinder system are shown from the top, front and side in Figure 2-2 and Figure 2-4. An expanded front view of a two–cylinder system is shown in Figure 2-3.

1. Loosen the cylinder retaining fingers and orient them at 90 degrees.
2. Loosen the three (3) valve assembly slide screws. Slide the valve assembly to the left and up as far as it will go. Re–tighten the slide screws to hold the valve assembly out of the way while the cylinders are installed.
3. Select the bottom cylinder by matching the number on the stand to the cylinder number on the cylinder label. Lift it into the cylinder support blocks. Ensure that the pump base plate is inserted into the slot provided in the stand assembly. Also, ensure that the sensor cable is on top of the pump.
4. Route the sensor cable from its connection at the pump side cover to the cable retainer above the pump. Insert the sensor cable in the four cable retainers that are mounted on the stand.
5. Plug the sensor cable into the appropriate connector on the CMD–5000.
6. Connect the motor cable to the CMD–5000.
7. Loosen the cylinder retaining fingers, then tighten them so that they hold the cylinder in place. Repeat this procedure for the other pump cylinders in your system.

IMPORTANT
Be sure to install each cylinder into the correctly–numbered space. Stands for two cylinders have Cylinder A on top and Cylinder B on the bottom. A 3–cylinder system (mounted on a 4–cylinder stand) has the cylinders in the following order, going from top to bottom: 2A, 2B–not installed, 1A, and 1B. A 4–cylinder system has the cylinders in the following order, going from top to bottom: 2A, 2B, 1A, 1B.

NOTE: The plumbing for the 5000 Series pumps uses the Autoclave W125 (Speedbite) fitting port. (The one exception is systems with pump cylinder model C–5000-20K, which uses the Autoclave F250C fitting port.)

8. Loosen the retaining screws on the valve assembly and slide the assembly down and to the right so that the Autoclave Speedbite fittings engage the pump cylinder barrels. Some adjustment may be necessary to get a good fit.
9. First tighten the fittings by hand, then finish tightening them using the angle wrench provided in the special tool kit.
10. For the C–5000-20K cylinders, connect the valve assembly fittings to the pump cylinders using the following orientation:
    - the safety rupture disk holders point toward the stand,
    - the transducers point away from the cylinders, and

- the valves mount away from the stand.

11. When the stand is fully assembled and placed in the desired location, adjust the leveling feet so that the cylinders slope upwards from the motor to the cylinder barrel. This slope is recommended so that any trapped gas in the cylinder barrel is expelled when the cylinder fills with liquid.
12. Connect the power cords to the appropriate power connection, preferably through an Uninterruptable Power Supply (UPS). See Chapter 10. Do NOT turn on the CMD-5000, however, until steps 13-16 have been completed!
13. Connect the data link cable from the CMD–5000 to Port A of the Serial Expander/Isolator. If you have two controllers in your system, then connect the data link cable from the second CMD-5000 to Port B of the Serial Expander/Isolator.
14. Connect the RS-232 cable between the Serial Expander/Isolator to a serial port on the computer (usually serial port 1 or COM 1). Then connect the keyboard and monitor cables to the computer.
15. Connect an air supply to the valve solenoids. This supply is connected with a 1/4" plastic tube to the bottom of the valve solenoid manifold. The air supply should be clean, dry air regulated between 60 and 100 psi (4.0 and 6.8 bar)

IMPORTANT

User–supplied tubing should also be installed from the port of each of the Safety Rupture Disks to an appropriate receptacle in order to prevent fluid from spraying into the atmosphere in case the rupture disk is activated. For more information about the Safety Rupture Disks, refer to Chapter 5 and Chapter 11.

16. If you purchased a computer with your system, the computer is set up with the Windows operating system and the necessary Quizix PumpWorks programs. If you did not purchase a computer with your system, refer to the PumpWorks User's Manual for additional instructions on installing PumpWorks on your computer. Insert the PumpWorks disk into your computer. Using either Windows Explorer or File Manager, double-click on or run "setup.exe". The PumpWorks wizard application guides you through the software installation. **Do not start PumpWorks yet.**
17. The CMD-5000 Dual Controller Driver has a two-digit display, which is labeled "Pump Number". Using letters, numbers, or a combination of the two, this display can convey overpressure or underpressure errors, communication errors, driver errors, or the absence of a cable. If no errors are present, the two-digit display will show the pump number (1,2,3, and so on). Locate this display on the CMD-5000.
18. Watch the two-digit display when you turn on your pump controller. First, you will see all segments of the display light at once, briefly. Next the display will flash the boot version number (currently 3.6). Next, the right-hand digit will light one segment at a time to indicate that the basic pump controller hardware diagnostics are being performed. Next, the software diagnostics are performed and the left-hand digit will display numbers 1-8 in succession. In the final step, "do" will flash alternately with "0". The "do" stands for digital overpressure. As a safety precaution, systems are shipped with a safety pressure set at -50 psi. You will need to reset the safety pressure before operating the system.

19. Now you are ready to install your C-5000 pump cylinders onto PumpWorks. Go to Start | Programs | and double click on PumpWorks 95-NT. PumpWorks will automatically search for new pumps.
20. When PumpWorks finds a new pump, the following message will display: “CMD-5000 found on Com 1: expander Port A (or B,C, or D). Do you wish to install?” Click on “Install”.
21. PumpWorks will ask you to “Enter User Name for New Pump.” The default pump name is Pump 1, Pump 2 and so on. If you don’t want to change the name now, you may do so at any time from PumpWorks main window. Click on “Install”.
22. When PumpWorks starts, the “Pump Data & Controls” window will be showing. You will know that your pump has been installed because the pump name will appear in black letters (either Pump 1, Pump 2 and so on or the user-given pump name). If no pump is present, the default pump name appears in gray letters. Also, the pump data fields will contain numbers instead of question marks.
23. Before using the system, perform the system checkout and operation procedures provided in Chapter 3. Use the connection checklist in Chapter 3 for an easy way to ensure that all cables and plumbing are properly connected. Chapter 3 also guides you through the initial process of checking out the valves and pump cylinders and filling the system with fluid.

2.4 Setting Up a High Temperature System: Oven Installation

The Quizix 5000 Series Pump System is available in a high temperature version to allow fluid delivery at reservoir temperatures. When installing a high temperature system into and near an oven, follow these guidelines for each component.

2.4.1 Pump Cylinders

The high temperature version of the C-5000 pump cylinder has a 6" extension between the cylinder housing and the motor. The cylinders must be placed in the oven so that the motor extension tube extends through the oven wall, with the entire motor and fan cooling assembly residing outside of the oven. Generally, one hole must be cut in the oven wall for each cylinder. The Quizix High Temperature Stand provides a convenient method of mounting pairs of pump cylinders inside ovens. See Figure 2-5.

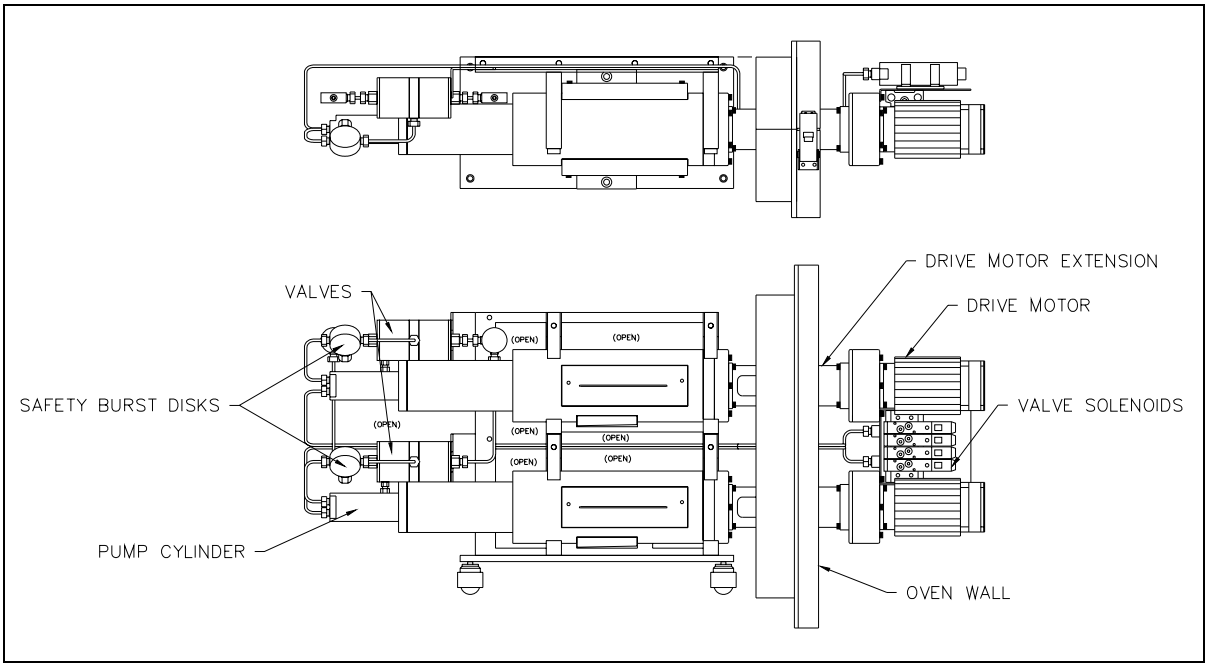

Figure 2-5 High Temperature Stand for the 5000 Series Cylinders

2.4.2 CMD–5000 Dual Controller Driver

The CMD-5000 must be placed near the pump cylinders and must be outside of the oven. Connect the motor and sensor cables to the appropriate cylinder connectors. It is highly advisable to keep the motor cables short. Standard 2–meter motor extension cables are available from Quizix, but it is recommended not to use these extensions, if possible.

2.4.3 Transducers

The standard pressure transducers supplied with the system are designed for operation to 70°C. They can be used at temperatures up to 80°C inside an oven without severely shortening their lifetime. However, for temperatures above 80°C, the transducers must be mounted outside the oven.

2.4.4 Valves

A high temperature version of the valve is available that can be heated to 160°C. However, the pilot solenoids cannot be placed in an oven. The pilot solenoids should be placed outside the oven with air tubes connecting the solenoids and the valves. Use high temperature tubing (Teflon®) and compression fittings.

2.4.5 Cables

For oven–mounted systems, the location of the pump cylinder, CMD-5000, transducer, and pilot solenoid manifold determines the length of each cable. Quizix supplies cables to user–specified lengths for most high temperature systems. If a cable is not long enough for your application, consult Table 2-1.

Table 2-1.Cabling Chart		
Cable Label	**Connection**	**Remedy**
motor cable	cylinder to CMD-5000	Order a motor cable extension 2 meters long. Note: If possible, avoid this extension because of high frequency signals.
sensor cable	cylinder to CMD-5000	Order the correct length.
transducer & valve cable	CMD-5000 to transducers and pilot solenoid manifold	Order the correct length. Note: If possible, avoid long cables to reduce extraneous noise
RS–232 cable	serial expander/isolator to computer	Available at computer stores as a 9–pin male–to–female RS–232 cable.
Data link cable	CMD-5000 to serial expander/isolator	Order the correct length.

More information about the differences between the standard version of each component and the high temperature version of the component is available in the High Temperature Option section of Chapter 7 (C-5000 Pump Cylinder) and Chapter 8 (Valves and Plumbing). For a full description of all plumbing and cables to be connected, see Chapter 8, Valves and Plumbing, and Chapter 9, System Cables.

Refer to the steps in Section 2.3 to complete the process of setting up your system and installing the pumps onto PumpWorks. Before using the high temperature system, perform the system checkout procedures provided in Chapter 3.

2.5 Power Considerations

The CMD-5000 operates on AC current at 120, 220 or 240 volts. The CMD-5000 is compatible with the voltage and type of outlet used in the country to which the pump system was shipped.

At the 120 volt setting, Quizix components operate over a 100–130 volt range, and 47–63 Hz. At both the 220 and 240 volt settings, Quizix components operate over a 200–250 volt range, and at 47–63 Hz. The voltage setting on the CMD-5000 can be changed, if necessary. See Chapter 10, Section 10.3.

If you ordered a computer with your Quizix pump system, it is also set for the voltage in use in your country. See the operating manual for your computer for further information about its power specifications.

Electronic equipment, such as computers and the Quizix controller, can be affected by brief power interruptions and by power line surges and spikes. An Uninterruptable Power Supply (UPS) can provide back–up power capabilities to prevent any interruption in pump operation when power interruptions or surges occur. It is strongly recommended that users interested in obtaining continuous fluid flow over extended periods of time, use a UPS with their system

to prevent disruption to an experiment. See Chapter 10, System Power, for further information on UPSs.

2.6 Requirements for Air Supply

The valves used in the Quizix Pump System are air–actuated. Air is taken into the system at the solenoid manifold, then air tubes connect the solenoids and the valves. The air inlet fitting at the bottom of the manifold, which is labeled “P”, has a 1/4” quick–disconnect fitting. You should insert a 1/4” tube into this fitting to connect the system with a pressurized air source.

A standard laboratory air supply or an air compressor may be used. The air should be clean, dry, oil–free, and regulated at 60-100 psi (4.0 - 6.8 bar). See Chapter 8 for further information regarding the valves, pilot solenoids and air supply.

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3 SYSTEM CHECKOUT

This chapter provides important safety checkout procedures designed to help ensure the safe operation of your 5000 Series Pump System.

IMPORTANT
The safety procedures are essential to safe operation of the Quizix pump system. It is strongly recommended that you follow them carefully.

Because of the extremely high pressures achieved by Quizix pumps, the importance of these safety measures cannot be overemphasized. If they are followed, the Quizix 5000 Series Pump System is designed to operate safely. However, as with most machinery, system safety depends on following proper operating procedures. Carelessness can be dangerous!

It is also strongly recommended that you follow these checks and procedures in each of the following situations:

- When the pump system is first received from Quizix.
  Although all systems are carefully checked before shipment, it is necessary to ensure that no damage occurred during shipment.
- After any changes are made to any of the components or plumbing.
  That is, after moving the system, reconfiguring it, or making any other adjustments that require you to disconnect and then reconnect the cables or plumbing.
- If the system has not been operated for more than one month.

3.1 Verification of All Cable and Plumbing Connections

It is absolutely essential that all cable and plumbing connections are made correctly. The system can seriously malfunction if cables are switched or tubing is connected improperly.

For example, on the CMD-5000 Dual Controller Driver, if the motor cable from cylinder A is plugged into the connector for cylinder B and the cable for cylinder B is plugged into the connector for cylinder A, the system will not operate properly. It could generate high pressures, resulting in the rupture of the safety burst disk.

As another example, if the valve cable strand labeled #5 were plugged into solenoid #6, the system would not operate properly. Only a careful and thorough visual check can prevent this situation.

PumpWorks software can detect if all cables are connected, but it cannot determine if they are connected in the right places. Use the cable connection checklist shown in Section 3.1.1. This is the most basic and most important checkout. All plumbing and cables are labeled, and many are color–coded.

IMPORTANT
It is strongly recommended that you carefully double–check all cable and tubing connections each time you disconnect and then reconnect them.

3.1.1 Connection Checklist

The purpose of this safety check is to make sure that all the cables and tubing are connected in the right places. The system can seriously malfunction if the cables are switched or tubing is connected improperly.

1. **Motor Cables – from Pump Cylinder to CMD-5000 Dual Controller Driver**
   Make sure each motor cable is plugged into the correct connector for that cylinder. For a 4-cylinder system, connect cylinder 1A into the receptacle labeled "Cylinder A" on the **first** CMD-5000; connect cylinder 1B into the "Cylinder B" receptacle; connect cylinder 2A into the receptacle labeled "Cylinder A" on the **second** CMD-5000; and connect cylinder 2B into the receptacle labeled "Cylinder B".
2. **Sensor Cables – from Pump Cylinder to CMD-5000 Dual Controller Driver**
   Make sure each sensor cable is plugged into the correct connector for that pump cylinder. The sensor cables follow the same pattern as the motor cables.
3. **Transducer & Valve Cables – from CMD-5000 Dual Controller Driver to Transducers and Pilot Solenoid Manifold**
   Make sure each numbered cable branch is plugged into the transducers and pilot solenoids with the same number. For example, cable branch 1 into pilot solenoid 1. Also make sure each numbered cable branch is plugged into the pressure transducer with the same number. For example, cable branch A into pressure transducer A mounted on pump cylinder A.
4. **Data Link Cable - From the CMD-5000 to the Serial Expander/Isolator**
   Make sure the data link cable from the pump controller is connected to Port A of the serial expander/isolator. If you have two pump controllers, the second one's data link cable should be connected to Port B.
5. **RS–232 Cable – from Serial Expander/Isolator to Computer**
   Most users choose serial port 1 on their computer for the pump system.
6. **Color–coded Air Tubing–from Pilot Solenoids to Valves.**
   At both the solenoid end and the valve end, check to ensure that the tubing color matches the color on the fitting. For example, the orange solenoid fitting should contain orange tubing and the orange tubing should be plugged into an orange–labeled valve fitting. On 4-cylinder systems, each color is used twice.The colors used on pump cylinder 1A are used again on pump cylinder 2A. The colors used on pump cylinder 1B are used again on pump cylinder 2B. The air tubing connected to cylinders 2A and 2B will have a black band in addition to the color used on the air tubing connect to cylinders 1A and 1B.
7. **Fluid Tubing**
   Make sure the tubing from the center port of each valve goes to a safety rupture disk holder and then into the top hole on the end of the cylinder barrel. The tubing from the transducer connects to the lower fitting on the end of the cylinder barrel. (For C–5000-20K cylinders, one port on the cylinder barrel connects to a cross, onto which, a safety

rupture disk and transducer should be connected.) Trace all tubing connections to make sure the plumbing is complete and fittings are properly tightened. Connect tubing to the port of the safety disk holder for fluid release if the safety rupture disk is activated by excessive pressure.

8. **Fluid Inlet and Outlet**
   Be sure to connect your fluid source to the fitting labeled “fluid inlet”. The output of the pump is available through the fluid outlet line and will be at the flow rate or pressure the user specified in PumpWorks.

3.2 Valve Check

Ensure that the valves are working properly by conducting a visual and auditory check. There are small red indicator lights on the pilot solenoids. The light is ON when the corresponding valve is open; the light is OFF when the corresponding valve is closed.

1. Turn on the computer and the controller. Connect the compressed air supply to the pilot manifold. It is assumed that PumpWorks is installed on your computer already and is running. (If not, refer to the PumpWorks User’s Manual, for help with this step.)
2. Use the Pump Data & Controls window in PumpWorks to open and close each cylinder’s fill and deliver valves. Begin by selecting the fill valve for Cylinder 1A; click on its button to open and close it.
3. Verify that the light on the solenoid marked “1” is OFF when Cylinder 1A's fill valve is closed. Open this valve and verify that the light for Solenoid 1 goes ON. Also, listen for a “popping” sound as the valve opens and closes.
   - If the light goes ON and OFF for a different solenoid than the one you are controlling on the computer, the valve solenoid cables are switched and must be reconnected properly.
   - If the light does not go ON or OFF, either the controller or the solenoid is malfunctioning.
   - If you do not hear a distinct popping sound when each valve opens and closes, then there is not adequate air pressure to operate the valves. Check the tubing from the solenoids to the valves and check your pressurized air supply.
   - Repeat this procedure for the cylinder 1A deliver valve and for each of the other valves in your system. See Figure 8-2 in Chapter 8 for an illustration of all of the valve connections to be checked.

3.3 Pump Cylinder Check

This safety check involves running each pump cylinder manually through one full piston stroke (retract and extend) and watching the piston move. Ideally, this test should be run with no liquid in the system. Unless the pumps are already filled with liquid, just use air. If the pumps contain liquid, you can proceed with the test, but be aware that with liquids, pressures can rise rapidly when the pump cylinders are extending.

1. It is assumed that you have just completed the valve check described in the previous section and that PumpWorks is operating. Set the Safety Pressure for the cylinders you are testing to 100 psi (700 kPa) using the Main-Set Pump Safety Pressure window.
2. Set the Operating Mode to Mode 1, which is the Independent Constant Rate mode.
3. Set the Flow Rate at approximately 20% of the maximum allowable flow rate (3 milliliters per minute for an C–5000-10K cylinder). The maximum flow rate is shown by PumpWorks in the Set Flow Rate window. At this rate, a full piston stroke takes about three minutes.
4. Set the direction to retract for each cylinder. However, if the piston position reading for any of the pump cylinders is at Max Retract, set the direction for that cylinder to extend. This is because, if the piston is at its maximum retracted position, the piston must now extend.
5. Set the valves so that the air or liquid displaced will not build up pressure. Usually, this means opening all fill valves; deliver valves may also be opened.
6. Start cylinder 1A by pressing the "Press to Start" button. View pump cylinder 1A through the side cover to see the piston move. Ensure that the cylinder labeled "Cylinder 1A" is actually the cylinder in which the piston is moving. If a different cylinder operates when you press the "Press to Start" button for cylinder 1A, then a cable connection is wired improperly and needs to be corrected.

   On ambient temperature systems, the piston can be viewed through the plastic side covers on the cylinder. The piston is not visible in the high temperature systems that have metal side covers. If you have a high temperature system, listen for the sound of the piston running and stopping. Also, watch the piston position that is displayed on PumpWorks.
7. When the piston reaches the end of its stroke, it automatically stops and displays Max Retract as the position. The direction automatically switches from retract to extend for cylinder 1A. Start the pump cylinder again and view the piston through the side cover until it reaches its Max Extend position. Also, listen for the sound of the piston running and then stopping.
8. Repeat this procedure for each pump cylinder. Set the direction to retract for one piston stroke, then extend for one stroke. Look and listen each time for correct operation.

This check indicates that PumpWorks, the controller, and the limit switches in the pump cylinder are all working properly, and the system is cabled correctly. If you do not see the piston moving in the correct cylinder or hear the motor running each time, you must do additional troubleshooting. Do not proceed further until your system has passed this check.

3.4 Filling the Pump System with Liquid

If your pum system does not have liquid in it, add it at this point. Connect the fluid inlet tubing to a fluid supply and the outlet tubing to a drain. Fill each cylinder manually by doing the following procedure.

1. To fill a cylinder with fluid, leave the safety pressure at 100 psi and set the flow rate to 50% of the maximum rate (7 ml/min for the C–5000-10K cylinder).

2. Open the fill valve, close the deliver valve, set the direction to retract, and start the cylinder to initiate the filling process for cylinder 1A.
3. When the cylinder reaches the Max Retract position, close the fill valve, open the deliver valve, switch the direction to extend, then press "Press to Start" to initiate the pumping process for cylinder 1A. On this first pumping stroke, mostly air is delivered out of the fluid outlet fitting.
4. Wait until the Max Extend position is reached, then repeat Steps 2 and 3 three times, ending with a retract stroke so that the cylinder barrel is full and all air is flushed out. Check to see that fluid has been taken from the fluid supply, and that some fluid has been pumped out through the fluid outlet during this process.
5. Repeat this procedure for each cylinder in your system, ending with all cylinders full of fluid and the pistons in the Max Retract position.

3.5 Pressure Transducer Check

Because the pump system can reach extremely high pressures very quickly, it is absolutely essential that the pressure transducers be checked carefully. To do this, use the following procedure.

1. It is assumed, that at this point, each cylinder is full of liquid and each piston is in the Max Retract position. Close both valves (fill and deliver) for cylinder 1A.
2. Set the rate to 20% of the maximum rate (3 ml/min for C-5000-10K model cylinders).
3. With the safety pressure still set at 100 psi, and the direction set to extend, start the cylinder. Watch the pressure reading on the software's Main Window until it exceeds 100 psi and is stopped by the digital overpressure control system. If the cylinders are filled with fluid, this should occur with less than 0.5 ml of fluid pumped.
4. Stop the pump cylinder if:
    - The pressure reading does not stop increasing when it reaches 100 psi (700 kPa). You must do further trouble shooting due to an apparent pressure transducer or pump controller malfunction. The likely cause of this is either the pressure transducer or the motor is cross-wired. For example, pump cylinder 1A's pressure transducer may be connected to pump cylinder 1B's connector.
    - The pressure reading does not begin to increase after several seconds. The most likely cause of this problem is there is no fluid in the pump, which can be caused by: (1) an air leak in the fluid tubing allowing air to enter the pump system, (2) the fluid inlet tubing is clogged, preventing fluid flow in the tubing, or (3) the fluid is too viscous, or thick, to be pulled into the pump.

It is a good idea, at this time, to go through the pump and check all fluid fitting connections to make sure they are tight.

Another possible cause is the pressure transducer may be broken and not reporting the pressure. Open the fill valve and listen for pressure being released. If there is pressure being released, you probably have a pressure transducer failure or the pressure transducer is cross-

wired. **NEVER operate the system AT ALL if you have any reason to believe a transducer has failed.**

Repeat this procedure for each cylinder in your system. Do not proceed further until your system has passed this check.

After completing each of the above checks, you can proceed to operate the system. Remember, however, that if you disconnect any of the major components, reconfigure the system, change the plumbing, or make any other adjustments that involve disconnecting and reconnecting any of the cables or tubing, you should do each of these safety procedures again.

4 PUMP OPERATING BASICS

In this chapter we discuss the basics of operating your 5000 Series Pump System using PumpWorks© Software. Included in this chapter are the following sections:

- Introduction to Using PumpWorks, Section 4.1
- PumpWorks Main Window, Section 4.2
- Pump Data & Controls Window, Section 4.3
- Set Safety Pressure, Section 4.4
- Errors Present, Section 4.5

4.1 Introduction to Using PumpWorks

The 5000 Series Pump System is operated using Quizix PumpWorks© Software, which runs on a PC-compatible computer (486 or Pentium® based, 66 mhz minimum), using Windows 95, Windows 98, Windows NT, Windows 2000 or Windows XP operating system. To use your 5000 Series Pump System effectively, you must know what you want to do with the fluid you are pumping and how to utilize PumpWorks to accomplish this.

The 5000 Series Pump System uses operating modes to pump fluid in a wide variety of ways. First, the user must decide whether to choose an independent or paired operating mode. If a single stroke volume (the amount of fluid the cylinder barrel holds) is sufficient for the desired flow, then independent cylinder operation is possible. If multiple stroke volumes are needed, but discontinuous flow is acceptable, then an independent cycled mode may be a good choice. If smooth continuous fluid flow of more than one cylinder stroke volume is needed, then paired cylinder operation is required.

The second decision is whether the flow should be at constant rate or constant pressure. For constant pressure operation, decide if the output pressure of the pump is to be held constant or if the pressure across a portion of the flow loop is to be held at a constant (constant delta pressure). Constant delta pressure requires the user to interface an external delta pressure transducer to the CMD-5000 Dual Controller Driver interface connector in order for the controller to be able to read this pressure.

Decision number three involves how you want fluid to flow in relationship to the pump. Will the flow of fluid be out of the pump (delivering fluid) or into the pump (receiving fluid)? Once you decide what you want the pump to do, you then need to use PumpWorks and set up your pump to accomplish what you want. The following section is a brief introduction to PumpWorks. For more detailed information about PumpWorks, see the PumpWorks User's Manual.

4.2 PumpWorks Main Window

In this section, we will discuss the basic parts of the window that opens when PumpWorks is initialized.

4.2.1 Windows

PumpWorks is a windows-based software program. Most of the menu options, when accessed, cause a window to open. When more than one window is open, the user can choose to either tile, individually arrange, or cascade the open windows. The tile command arranges all open windows across a screen, giving each one the same amount of space. The cascade command arranges all open windows so just their title bars show. To make a window active, click on the desired window.

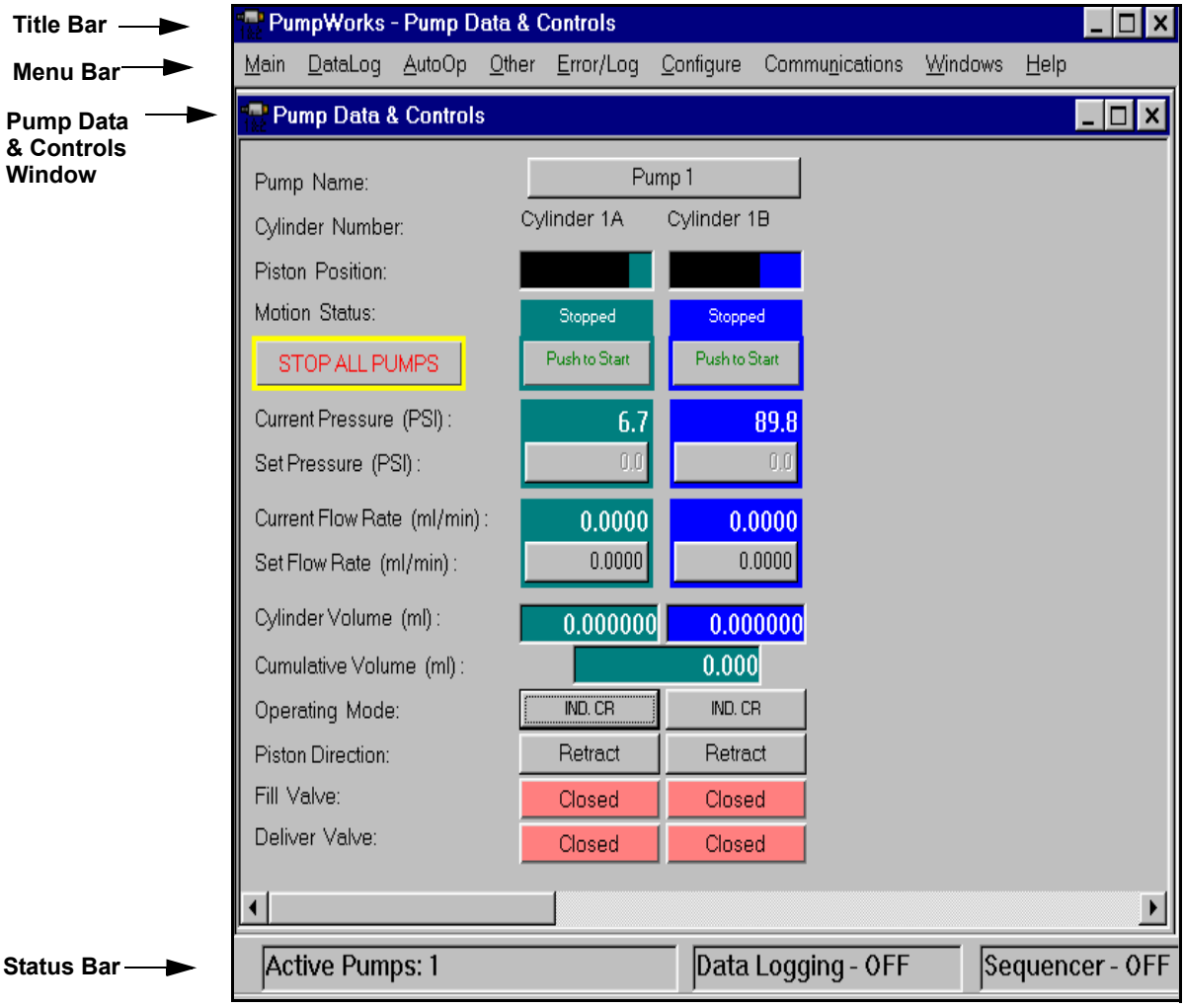

Figure 4-1 PumpWorks Main Window

4.2.2 Title Bar

The title bar appears at the top of the main window. The title bar lists the currently active window.

Figure 4-2 Title Bar

4.2.3 Menu Bar

The menu bar appears at the top of the main window in PumpWorks, below the title bar. The menu bar has nine pull-down menus. Each pull-down menu contains options which allow the user to regulate an aspect of their pump system. See Figure 4-3.

Figure 4-3 Menu Bar

4.2.4 Pump Data & Controls Window

PumpWorks Pump Data & Controls window, also referred to as the main window, appears when PumpWorks is initialized. See Figure 4-4 below. The main window is the core of PumpWorks and displays information and settings for up to eight pump cylinders.

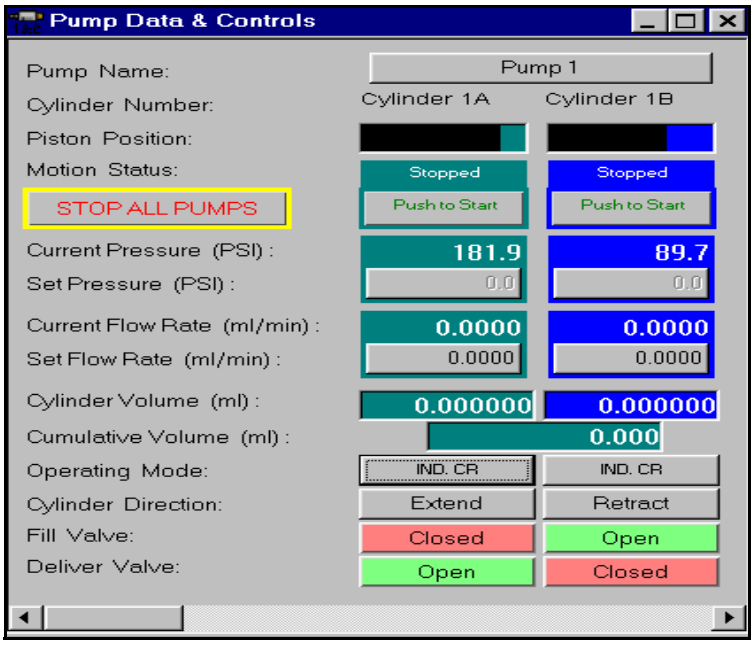

Figure 4-4 Pump Data & Controls Window

4.2.5 Status Bar

The status bar appears at the bottom of the main window in PumpWorks. The status bar displays messages regarding the status of the pump controller(s), data logging, sequencer, and error messages. See Figure 4-5.

Figure 4-5 Status Bar

4.2.6 Dialog Boxes

PumpWorks makes extensive use of dialog boxes when some menu selections or commands are initialized. Dialog boxes contain information and a box, or checklist, for the user to enter information.

4.3 Pump Data & Controls Window

The Pump Data & Controls window contains key operating information about all pump cylinders in a user's pump system. This information is continually updated while the pumps are running. Titles appear in the left column and data appears to the right of the titles. The following information is available:

- •Pump Name
- •Cylinder Number
- •Piston Position
- •Motion Status
- •Stop All Pumps Button
- •Current Pressure
- •Set Pressure Button
- •Current Flow Rate
- •Set Flow Rate Button
- •Cylinder Volume
- •Cumulative Volume
- •Operating Mode Button
- •Cylinder Direction Button (direction of piston movement
- •Fill Valve Button
- •Deliver Valve Button

In the following sections, we will discuss each of the above items in depth.

4.3.1 Pump Name

Quizix assigns a default name for each pump; each pump includes two C-5000 pump cylinders. The default names are Pump 1, Pump 2 and so on. The user has the option of entering a different name for each pump at any time. The user assigned name can be something that clarifies the pump's use, as in "Oil Pump" or "Brine Pump"; or something that clarifies the type of pump, as in "C-5000-10K Pump". If English is not the user's primary language, the pump name can be entered in the user's own language.

4.3.2 Cylinder Number

Quizix assigns a default number for each pump cylinder, which is Cylinder 1A and Cylinder 1B for Pump 1, Cylinder 2A and Cylinder 2B for Pump 2, and so on.This is considered paired numbering. The pump cylinders can also be numbered individually, which is Cylinder 1, Cylinder 2 for Pump 1, Cylinder 3 and Cylinder 4 for Pump 2, and so on. To change the cylinder numbers between paired and individual, go to PumpWorks System Settings window on the Configure menu.

4.3.3 Piston Position

The piston position field displays the position of the piston for each pump cylinder. The display is read from left to right, which is consistent with English text. The piston can be either fully retracted, called Max Retract; fully extended, called Max Extend; or somewhere in between.

- When at Max Extend, the piston is fully extended into the cylinder barrel and the black portion on the piston position display extends all the way to the right side of the Piston Position field, showing a solid black box.

- When at Max Retract, the piston is fully retracted out of the cylinder barrel and the piston position box displays a 10% black area on the left hand edge of the box.

The piston position field is a graphic display of the position of the piston. The motion status field is a written display of the position and current status of the piston. Watching the piston position and the motion status fields, the user can see and read an exact description of each piston's location and its actions.

4.3.4 Motion Status

The motion status field describes what each pump cylinder's piston is doing at any given time. Table 4-1 explains the possible motion status conditions, which are divided into two main categories: stopped conditions and run conditions.

Table 4-1 Motion Status Parameters 1 of 3

Condition	Description
STOPPED CONDITIONS	
Stopped	**The piston is stopped. See the piston position display to see how far the piston is extended into the cylinder barrel. The piston can be stopped near Max Extend, near Max Retract, or anywhere in between.**
Max Extend	**The piston is extended as far into the cylinder barrel as it will go. This is the piston's maximum, or most extended, position possible. The cylinder barrel has only a residual amount of fluid when the piston is in the Max Extend position.**
Max Retract	**The piston is retracted as far out of the cylinder barrel as it will go. Max Retract is the maximum or most retracted position possible. The cylinder barrel is full of fluid when the piston is in the Max Retract position.**
RUN CONDITIONS	
Extending	**The piston is in the process of extending, or moving forward, into the cylinder barrel. While the piston is extending, it is displacing the fluid, causing it to be pumped out of the cylinder barrel. This is known as delivering fluid.**
Retracting	**The piston is in the process of retracting, or moving backwards, withdrawing from the cylinder barrel. While the piston is retracting, fluid is being pulled into the cylinder barrel and filling it. This is known as receiving fluid.**
Stopping	**The piston is in the process of stopping. It is slowing down. Normally the piston is in the stopping condition for only a brief period before it is fully stopped.**

Table 4-1 Motion Status Parameters 2 of 3	
Condition	**Description**
Hold Ext	**Both the Hold Extend and Hold Retract conditions indicate that the pump is running, but the piston is not moving. It is running at a zero rate.** **A hold status message appears when the system is matching a pressure or servoing on a given pressure. At the moment that the pressure is matched correctly, resulting in no need to retract or extend further, a hold status message appears. By setting the flow rate to zero, the hold conditions also provide a way for the user to stop a pair of pump cylinders without cycling the valves or changing the pressure in them.** **The Hold Extend message indicates that when the rate is later changed to a non-zero value, or when the piston moves again as it servos on a specific pressure, it will extend. It indicates the next direction the piston will move.**
Hold Ret	**The Hold Retract condition is the same as Hold Extend, except that the piston will retract when it moves again.**
Servo Ext	**Both the Servo Extend and Servo Retract conditions indicate that the pump cylinder is in the process of servoing on a given pressure. Servoing means the pump is trying to achieve, or match, a given pressure. This occurs in paired operating modes when the standby pump cylinder is brought to the delivery pressure of the active pump cylinder. It also occurs when the pump cylinder is being operated in a constant pressure mode.** **The Servo Extend condition indicates that the piston is in the process of extending to achieve the desired pressure. It differs from the Extending condition because the piston will continue to extend only until the desired pressure is reached, and then will hold.** **When a pump cylinder is servoing, you can watch the motion status conditions hover around the servo and hold conditions.The pump cylinder will Servo Extend until the desired pressure is reached, Hold Extend for a moment, then Servo Extend again, Servo Retract because the pressure moved too high, then Hold again, etc.**
Servo Ret	**The Servo Retract condition is the same as the Servo Extend position, except that the piston is retracting in order to achieve a desired pressure. It differs from the Retracting condition because the piston continues to retract only until the desired pressure is reached, and then will hold.**
Other Messages	
Not Inst.	**The pump controller constantly verifies that all of the hardware necessary to properly operate a pump cylinder is present and properly connected. If any hardware is not present, a Not Inst (not installed) message appears in the motion status field. This message is the result of two or more of the following cables being disconnected: motor cable, sensor cable or the transducer and valve cable.**

Table 4-1 Motion Status Parameters 3 of 3	
Condition	**Description**
Error	**This message appears as a result of any of the error conditions shown on the Current Error field on the status bar. Typical errors may include overpressure conditions or the activation of a soft limit on the sensor board. Check the Current System Status on the Error/Log menu to find out which error is present.**
Undefined	**No pump has been installed to this location.**
Disabled	**A pump has been installed but communication between the pump and computer has been turned off. (Users can choose to disable a pump.)**

4.3.5 Start/Stop Pumps

A user can start or stop a pump in more than one way.

4.3.5.1 Starting Pump Cylinders

Pump cylinders can be started by any one of the following methods:

- Using the "Push to Start" button on the main window. Each operating pump cylinder has its own "Push to Start" button. For independent operating modes, each pump cylinder's "Push to Start" button will need to be pushed. For paired operating modes, only one "Push to Start" button needs to be pushed to start the pair of pump cylinders.

  To make certain a user knows the conditions of a pump cylinder before starting it, a Start Cylinder Confirmation dialog box appears and displays the pump cylinder's operating mode, cylinder direction and safety pressure. The question, "Do you want to start this cylinder?" requires a "yes" response before PumpWorks will start the pump cylinder. When stopping a pump cylinder, no confirmation box appears.

- From the menu bar, select Main | Start/Stop Pumps. This window displays all pump cylinders in a user's system. Any number of pump cylinders can be started or stopped, simultaneously, using this one window. No start confirmation box appears, when the Start/Stop Pump(s) button is clicked. The command is immediately acted upon by PumpWorks.

- Using the computer function keys. If this option is enabled in PumpWorks "System Settings" Window. Each function key is assigned to a particular pump cylinder in order; function key F1 to cylinder 1A, function key F2 to cylinder 1B, and so on. Pushing the appropriate function key will start a stopped pump cylinder in the same way that a Push to Start button does. Pushing the function key of an operating pump cylinder will stop that pump cylinder.

4.3.5.2 Starting Pump Cylinders in Independent Operating Modes

When a pump cylinder is set to an independent operating mode, the user needs to set the cylinder direction to either extend or retract, as desired. This is done on PumpWorks main window, using the cylinder direction button. If fluid is to be taken into the pump cylinder, the cylinder direction is set to retract. If fluid is to be delivered out of the pump cylinder, the cylinder direction is set to extend.

In independent operating modes, the user also needs to set the positions of the fill and deliver valves. These valves can be opened or closed depending on how the fluid is to flow. If the fluid is to be taken into the pump cylinder, the fill valve is opened and the deliver valve is closed. If fluid is to be delivered out of the pump cylinder, the fill valve is closed and the deliver valve is opened.

4.3.5.3 Starting Pump Cylinders in Paired Operating Modes

When the pump cylinders are set to a paired operating mode, all valve operations will be automatically set and controlled by the pump controller. The user does not need to preset the valves to achieve proper operation.

When operating in a paired operating mode, starting one of the pump cylinders in the pair starts the cylinder pair. The pump cylinder that is started becomes the active pump cylinder and the other pump cylinder becomes the standby pump cylinder until the first switchover. The direction of the active pump cylinder is determined by the operating mode selected. For delivery operating modes, the active pump cylinder extends first and the standby pump cylinder retracts. For receive operating modes, the active pump cylinder retracts first and the standby pump cylinder extends. For example, if you want to start a pump cylinder in paired constant rate delivery operation and start with cylinder A, it will be the active pump cylinder and will extend first with its deliver valve open and its fill valve closed. Cylinder B will be the standby pump cylinder and will retract first with its fill valve open and its deliver valve closed. When cylinder A has delivered all of its fluid and reaches Max Extend, it will switch with cylinder B. Cylinder A becomes the standby pump cylinder and Cylinder B becomes the active pump cylinder.

The user may choose to use PumpWorks Smart Start setting. With the Smart Start feature, PumpWorks and the pump controller decide the best way to start the cylinder pair by selecting which pump cylinder becomes the active pump cylinder and which becomes the standby pump cylinder. If the Smart Start feature is not used, the user must make these choices.

Paired Constant Pressure Bidirectional operating mode runs at a constant pressure by switching between delivering and receiving to maintain the set pressure. The valves will automatically switch as required. Please note that for constant pressure operation, the actual pressure, compared to the set point, determines the direction of the pump cylinder.

4.3.5.4 Stopping Pump Cylinders

Pump Cylinders can be stopped by using any one of the following methods:

- Using the "Push to Stop" button on the main window of PumpWorks. Each operating pump cylinder has its own "Push to Stop" button. For independent operating modes, each pump cylinder's "Push to Stop" button will need to be pushed. For paired operating modes, only one "Push to Stop" button needs to be pushed to stop the pair of pump cylinders.
- Selecting Main | Start/Stop Pumps from the menu bar of the main window of PumpWorks. This window displays all pump cylinders in a user's system. Any number of pump cylinders can be started or stopped simultaneously using this one window.
- Using the computer function keys (if this option is enabled in PumpWorks "System Settings" window). Each function key is assigned to a particular pump cylinder in order;

function key F1 to cylinder 1A, function key F2 to cylinder 1B, and so on. Pushing the appropriate function key will stop an operating pump cylinder in the same way that a Push to Stop button does.

Using the function keys to stop a pump cylinder has the advantage of stopping the pump cylinder quickly--even if the Pump Data & Controls window is not open. When operating two pump cylinders in a paired operating mode, the pair can be stopped by pressing either of the function keys that correspond to the pair.

- Using the "Stop All Pumps" button on the main window of PumpWorks. All operating pumps are immediately stopped.
- Selecting Main | Stop All Pumps from the menu bar of the main window of PumpWorks. All operating pumps are immediately stopped.

4.3.6 Current Pressure

The current pressure field displays a measurement of the pressure currently inside of the cylinder barrel. This measurement reading is taken from a pressure transducer. Each pump cylinder has one pressure transducer connected to it. The current pressure of each pump cylinder is displayed on the main window.

The default unit of measure for pressure is PSI (pounds per square inch). The user can change the unit of measure displayed to bar, millibar, kiloPascals, or megaPascals.

4.3.7 Set Pressure

The Set Pressure field allows a user to change the set pressure of a pump cylinder operating in a constant pressure mode to a different pressure. The pressure entered becomes the set pressure. If the pump cylinder is operating when a pressure is changed, the pump immediately adjusts to the new pressure.

4.3.7.1 Changing a Set Pressure

Change a single set pressure by clicking on the "Set Pump Pressure" button in the main window of PumpWorks and entering a new value. Each pump cylinder has its own Set Pump Pressure button.

4.3.7.2 Changing Multiple Set Pressures

To change the set pressure of one or more pump cylinders simultaneously, go to PumpWorks main window. Select Main | Set Pump Pressure from the menu bar and enter pressures for one or more pump cylinders in the Enter New Pressure box(s). Then click on Send Pressures to Pump(s). All new pressures are sent at the same time.

4.3.8 Current Flow Rate

The Current Flow Rate field displays the rate, or speed, that the pump cylinder is extending or retracting at. The default unit of measure for flow rate is milliliters per minute (ml/min). The user can set the unit of measure to either milliliters per minute or milliliters per hour.

4.3.9 Set Flow Rate

The set flow rate field allows a user to change the set flow rate of a pump cylinder operating in a constant rate mode to a different flow rate. The flow rate entered becomes the current flow rate. If a pump cylinder is operating when a flow rate is changed, the pump immediately adjusts to the new flow rate.

4.3.9.1 Changing a Set Flow Rate

Change the current flow rate for a single pump cylinder by clicking on the "Set Flow Rate" button in the main window of PumpWorks and entering a value. Each pump cylinder has its own Set Flow Rate button.

4.3.9.2 Changing Multiple Set Flow Rates

To change the current flow rate for one or more pump cylinders simultaneously, go to PumpWorks main window. Select Main | Set Pump Flow Rates from the menu bar and enter flow rates for one or more pump cylinders in the Enter New Flow Rate box(s). Then click on Send Rates to Pump(s). All new flow rates are sent at the same time.

4.3.10 Cylinder Volume

The cylinder volume field displays the actual volume of fluid that has been pumped by each pump cylinder since resetting the cylinder volume to zero. The default unit of measure for cylinder volume is milliliters (ml). The user can set the unit of measure to either milliliters, liters, or microliters.

4.3.11 Cumulative Volume

The cumulative volume field displays the combined volume pumped by a pump cylinder pair (1A and 1B, or 2A and 2B, and so on). This information is valid only when pump cylinders are operating in a paired mode, with one fluid continuously pumped alternately by two pump cylinders.

4.3.12 Operating Modes

The Quizix pump system offers many different operating modes. With the exception of two operating modes that are used for recirculating pump operation only, each operating mode includes the following three parts:

- Pump Cylinder Configuration, Section 4.3.12.1
- Pump Cylinder Operation Mode, Section 4.3.12.2
- Fluid Flow Direction, Section 4.3.12.3

4.3.12.1 Pump Cylinder Configuration

The 5000 Series pump cylinders can be configured in either of the following ways:

- **Independent -** Each pump cylinder works alone for a single stroke volume; or cycles for multiple stroke volumes for discontinuous flow.
- **Paired** - The two pump cylinders work together for continuous flow. One pump cylinder delivers fluid while the other pump cylinder is receiving fluid. The pressure

in the standby pump cylinder is matched to the pressure in the active pump cylinder just before switchover occurs.

4.3.12.2 Pump Cylinder Operation Mode

The 5000 Series pump cylinders can be operated in either of the following ways:

- **Constant rate** - Pump maintains a constant fluid flow rate.
- **Constant pressure**
  Constant outlet pressure - Pump maintains a constant user-set outlet pressure.
  Constant delta pressure - Pump maintains a constant pressure differential as measured by an external pressure transducer.

4.3.12.3 Fluid Flow Direction

The 5000 Series pump cylinders can pump in any of the following fluid flow directions.

- **Delivery** - Pump will deliver the fluid to an experiment.
- **Receive** - Pump will receive the fluid from an experiment.
- **Bi-directional** - Pump will deliver or receive fluid as required (paired constant pressure mode only).

4.3.12.4 Choosing an Operating Mode

To choose an operating mode:

- Click on the operating mode button for a particular pump cylinder. This is located to the right of the operating mode title. The Set Cylinder # Operating Mode window opens, as shown in Figure 4-6 below.

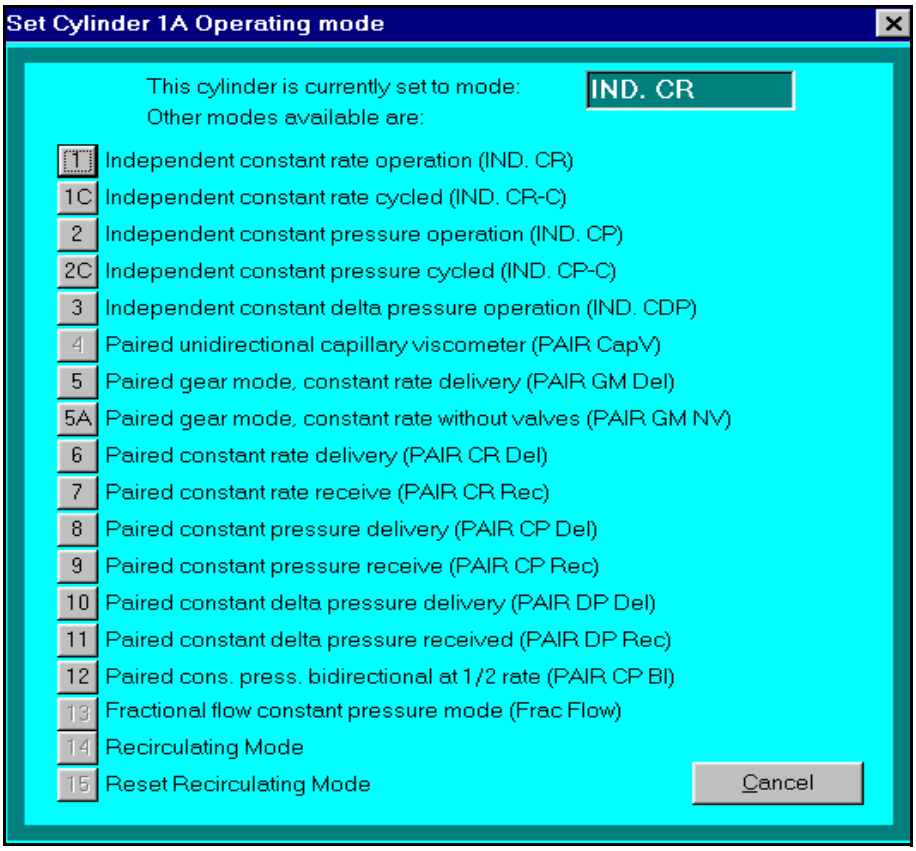
Set Cylinder 1A Operating mode
This cylinder is currently set to mode:
IND. CR
Other modes available are:
1 Independent constant rate operation (IND. CR)
1C Independent constant rate cycled (IND. CR-C)
2 Independent constant pressure operation (IND. CP)
2C Independent constant pressure cycled (IND. CP-C)
3 Independent constant delta pressure operation (IND. CDP)
4 Paired unidirectional capillary viscometer (PAIR CapV)
5 Paired gear mode, constant rate delivery (PAIR GM Del)
5A Paired gear mode, constant rate without valves (PAIR GM NV)
6 Paired constant rate delivery (PAIR CR Del)
7 Paired constant rate receive (PAIR CR Rec)
8 Paired constant pressure delivery (PAIR CP Del)
9 Paired constant pressure receive (PAIR CP Rec)
10 Paired constant delta pressure delivery (PAIR DP Del)
11 Paired constant delta pressure received (PAIR DP Rec)
12 Paired cons. press. bidirectional at 1/2 rate (PAIR CP Bl)
13 Fractional flow constant pressure mode (Frac Flow)
14 Recirculating Mode
15 Reset Recirculating Mode
Cancel

Figure 4-6 Set Cylinder # Operating Mode

The Set Cylinder # Operating Mode window gives the user a list of the possible operating modes available for their pump system. An operating mode is grayed if it is not available for the user's pump system.

- To set an operating mode, click on the operating mode's number, which is to the left of the operating mode name. The Set Cylinder # Operating Mode screen closes. Your pump is immediately changed to the new operating mode.

Quizix strongly recommends that you become familiar with all of the operating modes. A brief description of each operating mode follows, however, the PumpWorks manual explains operating modes in depth. Operating modes should be clearly understood before running any Quizix pump.

Table 4-2 Operating Modes		
Mode No.	**Operating Mode**	**Description**
Independent Operating Modes		
1.	**Independent Constant Rate (IND CR)**	In this mode, a single pump cylinder is operating in constant rate mode at a user-set rate. When a pump cylinder is operated in this mode, it either extends or retracts for only one piston stroke. The user sets the valves and the direction of the pump and the flow rate, then starts the pump cylinder for each piston stroke.
1C.	**Independent Constant Rate Cycled (IND CR–C)**	In this mode, a single pump cylinder is used to cycle back and forth to deliver fluid to an experiment. The active pump operates at the set rate. When the end–of–stroke is detected, the valves are switched, the direction changed, and the pump cylinder is refilled. During the refilling (standby, retract) stroke, the rate is determined by the return rate factor and the return rate minimum parameters. The fluid flow in this mode is discontinuous due to the refill stroke. After refilling, the cylinder will servo to the measured pressure at the end of the last stroke; then open the deliver valve and start the next stroke.
2.	**Independent Constant Pressure (IND CP)**	In this mode, a single pump cylinder is operating in constant pressure mode at a user-set pressure. Like Mode 1, when a pump cylinder is operated in this mode, it either extends or retracts for one piston stroke. The user sets the valves and restarts the pump cylinder for each piston stroke. The direction of pumping action is determined by whether the piston must retract (depressurize) or extend (pressurize) in order to achieve the specified pressure level. The user also sets the run pressure.
2C.	**Independent Constant Pressure Cycled (IND CP–C)**	In this mode a single pump cylinder is used to cycle back and forth to hold a constant pressure to an experiment. The pump cylinder may deliver or extend to hold pressure. When the end–of–stroke is detected, the valves are switched, the direction changed, and the pump cylinder is refilled. During the refill (standby, retract) stroke, the rate is determined by the return rate factor and return rate minimum. The fluid flow in this mode is discontinuous due to the refill stroke. After refilling the cylinder will servo to the set pressure, before opening the deliver valve and starting the next stroke. As long as pressure does not change much during the refill time, which can be less than one minute, the system will hold pressure.

Table 4-2 Operating Modes		
Mode No.	**Operating Mode**	**Description**
3.	**Independent Constant Delta Pressure (IND CDP)**	In this mode, a single pump cylinder operates at a constant delta pressure, as specified by the user. The pump cylinder will either extend or retract for one piston stroke. The user must set the valves and restart the pump cylinder for each piston stroke. The direction of pumping action is determined by whether the piston must extend or retract in order to achieve the specified delta pressure.(For example, across an experiment.)
Paired Operating Modes		
4.	**Paired Unidirectional Capillary Viscometer (PAIR CapV)**	This mode is designed especially for capillary viscometry experiments. In this mode, the pump cylinders operate like they are geared together. One pump cylinder is extending (delivering) while the other is retracting (receiving). The pump cylinders must be started so that their motions are opposite of each other (one fully retracted and one fully extended). The valves are operated to keep the fluid flow unidirectional and as free of pressure variations as possible with two pump cylinders.
5.	**Paired Geared Mode Constant Rate (PAIR GM CR)**	In this mode, two pump cylinders retract and extend continuously. The pump cylinder pair pumps at a constant rate and does not match pressures between pump cylinders prior to switchover. The system disregards pressure data except for overpressure errors. The motion of each pump cylinder is a mirror image of the other, because the standby pump cylinder does not pre–pressurize prior to switchover. This mode is most useful for flushing out a pair of pump cylinders or flushing out the plumbing network. You must specify the run rate for this mode. Before starting, place one pump cylinder at Max Extend and the other pump cylinder at Max Retract.
5A.	**Paired Geared Mode Constant Rate Without Valves (PAIR GM NV)**	This mode is identical to Mode 5, except that the valves are not switched. This mode is extremely useful for dynamic fluid leak tests.

Table 4-2 Operating Modes		
Mode No.	**Operating Mode**	**Description**
6.	**Paired Constant Rate Delivery (PAIR CR Del)**	In this mode, a pair of pump cylinders continuously delivers fluid at a constant rate, set by the user. Fluid pressure is determined by the pressure drop across the experiment. Unlike geared modes, the pressure in the standby pump cylinder is brought to the delivery pressure of the active pump cylinder before switchover, so fluid flow is pulseless.The user sets a flow rate when this mode is selected. The user does not set the run pressure or the direction. To begin operating a cylinder pair in this mode, determine which pump cylinder is to deliver fluid first (piston extend) and start that pump cylinder key so it will extend while the other (standby) pump cylinder retracts. Note: See Starting Pump Cylinders in Paired Operating Modes, Section 4.3.5.3,regarding relative piston position before starting up a pump cylinder pair.
7.	**Paired Constant Rate Receive (PAIR CR Rec)**	This mode is identical to Mode 6, except that the pump cylinder pair continuously receives (extracts) fluid from an experiment. In this case, fluid is received into the fluid outlet and expelled through the fluid inlet.
8.	**Paired Constant Pressure Delivery (PAIR CP Del)**	In this mode, a pair of pump cylinders continuously delivers fluid at a constant pressure, as set by the user. The flow rate varies as needed to maintain that pressure. Specify a run pressure when selecting this mode. You need not set a flow rate or direction. The direction of this mode is to deliver fluid through the fluid outlet. To begin, start the pump cylinder you want to deliver fluid first.
9.	**Paired Constant Pressure Receive (PAIR CP Rec)**	This mode is identical to Mode 8, except the pump cylinder pair continuously receives (extracts) fluid from the experiment. This mode is effectively a back–pressure regulator.
10.	**Paired Constant Delta Pressure Delivery (PAIR DP Del)**	This mode maintains a constant pressure differential by increasing or decreasing the flow rate to the fluid outlet. The fluid delivery rate and pressure varies as needed to maintain that differential pressure.
11.	**Paired Constant Delta Pressure Receive (PAIR DP Rec)**	This mode is identical to Mode 10, except the cylinder pair continuously receives (extracts) fluid through the fluid outlet.

Table 4-2 Operating Modes		
Mode No.	**Operating Mode**	**Description**
Paired Operating Modes		
12.	**Paired Constant Pressure Bidirectional Half Rate (PAIR CP BI)**	This mode is similar to Mode 8, in that it continuously maintains fluid at a constant pressure. However, in this mode, the piston is at the halfway point at switchover, and will either deliver or receive fluid to maintain the specified pressure level. The maximum continuous delivery or receive rate for this mode is one–half of the rate for Mode 8 or Mode 9 because the piston has only half of the full piston stroke available.
14.	**3, 5 or 7 Cylinder Recirculating (nCyl RECIRC)**	Recirculating operating modes are used when a fixed amount of fluid is to be circulated in a closed loop through a sample. Steady–state conditions can be achieved with this method of fluid flow. All recirculation modes require special software and hardware that can be ordered from Quizix as an option. • The 3– cylinder recirculating mode can circulate a single fluid. • The 5–cylinder recirculating mode can circulate two different fluids. • The 7–cylinder recirculating mode can circulate three different fluids.
15.	**Reset Recirculating Mode**	This is not an operating mode, per se, but is a setting used only by recirculating systems to exit the 3, 5, or 7–cylinder Recirculating Mode (Mode 14).

4.3.12.5 Independent Cylinder Configuration

In independent operating modes 1, 2, and 3, a single pump cylinder pumps fluid. The pump cylinder runs for only one piston stroke, then stops. At the end of each piston stroke, the user must open or close the valves and restart the pump cylinder using PumpWorks Pump Data & Controls window.

The basic limitation of the independent pump cylinder configuration is that the amount of fluid that can be delivered or received continuously is limited to the volume of the cylinder barrel. With only one pump cylinder operating, the piston can perform a single stroke, then has to stop to be refilled (or emptied, if it is receiving fluid). The stroke volume of each of the Quizix C-5000 pump cylinders is shown in Table 4-3.

Table 4-3 C-5000 Pump Cylinders Stroke Volume	
Model	**Stroke Volume (Typical)**
C–5000–2.5K	37 ml
C-5000-5K and C-5000-L-7.5K	21 ml
C-5000-10K and C-5000-L-10K	9.3 ml
C-5000-20K	5.2 ml

For example, a C–5000–5K pump cylinder with a full cylinder barrel, in Independent Constant Rate mode (mode 1), at a flow rate of 1 ml/min, would deliver fluid for 21 minutes and then stop because it had reached the end of its piston stroke and was empty.

Operation of an individual pump cylinder is most useful to provide overburden pressure to a core sample, or when the volume to be pumped is less than the stroke volume so that the single piston stroke limitation is irrelevant.

4.3.12.6 Paired Cylinder Configuration

Two pump cylinders can operate together, as a pair, to provide continuous flow. The two pump cylinders take turns being the active and standby pump cylinder. For example, in a deliver mode, the active pump cylinder is delivering fluid and the standby pump cylinder fills with fluid and pre–pressurizes to the delivery pressure level of the active pump cylinder. When the active pump cylinder has completed its piston stroke, there is a switchover. The standby pump cylinder becomes the active pump cylinder and the active pump cylinder becomes the standby pump cylinder.

In a paired configuration, two pump cylinders can pump fluid continuously for an indefinite period of time. Because the standby pump cylinder is pre–pressurized to the pressure level of the active pump cylinder, the fluid flow is pulseless. It is important to note that (except in Modes 4, 5, and 5A), the pump cylinder pair does **not** alternate in the usual sense: the pump cylinders are **not** just mirror images of each other's motion. The standby pump cylinder piston must move at a faster rate than the active pump cylinder piston so that it has time to pre–pressurize before switchover.

4.3.12.7 Mixed Configurations and Mixed Modes

Any combination of independent and paired pump cylinders is possible. For example, a system with four pump cylinders may be operated as two pairs, as four independent pump cylinders, or as one pair and two independent pump cylinders. However, pump cylinders operating as a pair must share the same pump controller. For example, pump cylinders 2A and 2B can be a pair, but pump cylinders 1B and 2A cannot.

The user can select different operating modes for each pump cylinder or pump cylinder pair. For example, in a system with three pump cylinders, two pump cylinders can be operated in Paired Constant Rate Deliver mode and one pump cylinder can be operated in Independent Constant Pressure mode to provide overburden pressure to a core sample.

4.3.13 Cylinder Direction (Direction of Piston Movement)

The piston, which is inside of the cylinder barrel, either extends into the cylinder barrel or retracts out of the cylinder barrel. As the piston moves forward it extends into the cylinder barrel, causing fluid to be displaced and pumped out of the cylinder barrel. The pump cylinder is therefore delivering the fluid either to an experiment or to a container. As the piston retracts, it pulls out of the cylinder barrel. As the piston pulls out of the cylinder barrel, fluid is pulled into the cylinder barrel. The pump cylinder is therefore receiving fluid, either from an experiment or from a container. The cylinder direction, then, refers to the pump cylinder either delivering the fluid (extend) or receiving the fluid (retract).

4.3.14 Fill and Deliver Valves

The fill and deliver valves (which are the two sides of a single Vindum Engineering CV Valve) are important for the successful operation of the pump cylinder operating modes. PumpWorks color codes the fill and deliver valve buttons green when the valve is open and orange/red when the valve is closed. The fill and deliver valves are opened or closed depending on the operating mode chosen and whether the pump cylinder is delivering or receiving fluid. To fill a pump cylinder with fluid, the fill valve needs to be open, allowing fluid to enter the pump as the piston retracts; and the deliver valve needs to be closed. To deliver fluid, the deliver valve needs to be open and the fill valve needs to be closed. Refer to the fluid flow diagram below which shows the basic fluid plumbing for a pump system with two pump cylinders. If the user needs to service the valves, refer to the Valve User Manual for information.

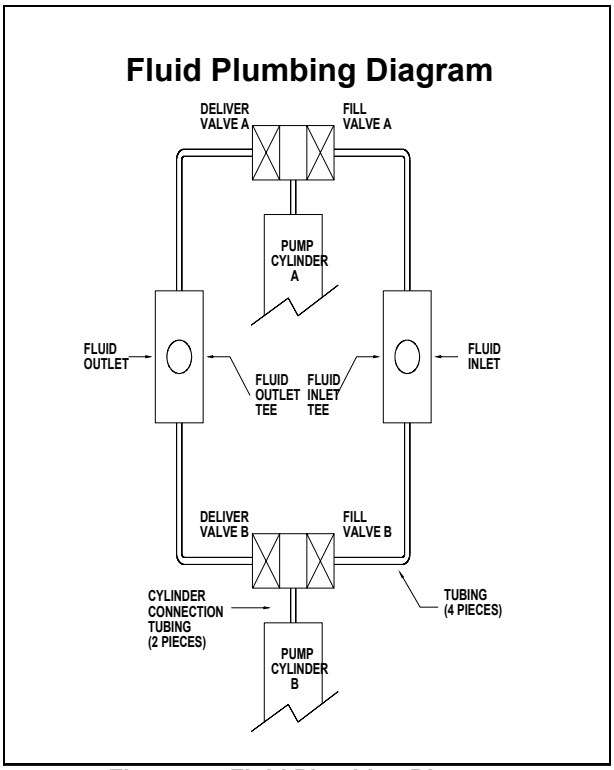

Figure 4-7 Fluid Plumbing Diagram

4.4 Set Safety Pressure

PumpWorks includes a safety pressure feature. PumpWorks will automatically stop a pump cylinder when the user-set safety pressure has been reached. When the pump is first powered up, the safety pressure is initialized to a negative pressure so that the user is required to enter a value that is correct for their pump. An “errors present” message will display on the status bar of the main window of PumpWorks until the user sets the safety pressure.

To set the safety pressure, go to PumpWorks main window and on the menu bar click on Main | Set Safety Pressure. Enter a pressure which is higher than the maximum pressure level you expect to reach during the normal course of your experiment.

4.5 Errors Present

When the status bar of PumpWorks main window shows “Errors Present”, a pump cylinder cannot be operated until the error is cleared. The Current Error Log, which is located on the Error/Log menu of PumpWorks main window, will give a description of the error and includes a button where a user can acknowledge that they have read the error. The user must also correct the condition that caused the error message. See Chapter 12, "Troubleshooting" for more information regarding error messages and how to clear them.

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5 SAFETY FEATURES

Quizix pump systems are capable of creating and maintaining very high pressures. Safe operation of these systems is a primary concern. The safety features described in this chapter are designed into all Quizix 5000 Series Pump Systems.

5.1 Cable Connections Sensing

To verify that all major components are present before a pump system can be operated, PumpWorks includes a feature that detects the connection of the following cables:

- Motor cable (pump cylinder motor to CMD-5000 Dual Controller Driver)
- Sensor cable (pump cylinder sensor board to CMD-5000 Dual Controller Driver)
- Transducer and Valve cable (pressure transducers and valve solenoids to CMD-5000 Dual Controller Driver)
- Data Link cable (CMD-5000 Dual Controller Driver to Serial Expander/Isolator)

If a connection is not detected, an error message is displayed on the system monitor and the pump cylinders stop operating. It is important to note that the cable connection sensing feature is only able to detect the presence of a cable; it cannot detect if it is the correct cable where more than one of a certain type of cable may be connected. For example, if the sensor cables are reversed (for example, the cable from cylinder A is plugged into the receptacle for cylinder B, and vice versa), PumpWorks cannot detect the problem. This is why it is of the utmost importance to always carefully check cable connections as described in Chapter 3, System Checkout Procedures.

5.2 Cable Labeling

Quizix labels all cables at both ends and labels the device to which they connect with unique label names. Color–coding is also used to simplify the identification of proper connector locations.

IMPORTANT
All cables are uniquely labeled and color–coded. It is important that components be mounted in their correct locations, and all cable markings match.

5.3 Overpressure Protection Safety Features

To prevent the 5000 Series Pump System from reaching excessively high pressures, multiple safety features are implemented. They are described in this section.

5.3.1 Digital Overpressure (Safety Pressure Setting)

The most basic of these safety features is digital overpressure, which is monitored in the controller software. With this feature, the user specifies a safety pressure at a level higher

than the expected running pressure. If the system exceeds the safety pressure setting, a digital overpressure error message is displayed on the system monitor and the cylinders stop pumping. The controller stops the pump when the safety pressure is reached. Due to momentum, if the piston is moving forward at a fast rate when the overpressure event is detected, the system pressure may exceed the safety pressure before the cylinder comes to a complete stop.

5.3.2 Digital Underpressure

The transducer for the Quizix pump system has been selected so that at zero pressure, the transducer output is 0.5 volts. The controller includes a safety feature that provides an error message if the transducer voltage drops below a certain level or pressure signals are not received by the controller. In this case, PumpWorks assumes that there is a transducer failure. A digital underpressure error message is displayed on the system monitor and the cylinders stop pumping.

5.3.3 Analog Overpressure

The analog overpressure feature is implemented in the controller hardware, whereas the digital overpressure and underpressure features are part of the software. The analog overpressure feature limits the maximum value allowed from the A/D converter. It is fixed at approximately 5% over the maximum pressure specification of the pump system. It cannot be set by the user. If an analog overpressure error occurs, the cylinders stop pumping and an error message is displayed on the system monitor.

5.3.4 Safety Rupture Disk

The safety rupture disk is the final safety feature designed to prevent the pump system from exceeding a specified pressure. For example, for pump cylinders rated at 10,000 psi, the safety rupture disk activates at approximately 12,500 psi (see Table 5-1 for other models).

The safety rupture disk is activated if there is a transducer failure that cannot be detected by the normal safety systems. It is also activated in the unlikely event of a hardware or software failure where the pump system does not respond to normal controls. In this case, the safety rupture disk activates to protect the pump, tubing, and external components from damage.

IMPORTANT
It is very important that the you install tubing into the fitting of the relief fluid exit and that it is plumbed to an appropriate receptacle. This prevents fluid from spraying into the atmosphere in case the rupture disk is activated. This is particularly important if you are using flammable or highly corrosive fluids.

Table 5-1 Safety Rupture Disk Ratings		
Cylinder Model	**Maximum Operating Pressure**	**Safety Rupture Disk Rating**
C–5000-2.5K	2,500 psi	3,500 psi
C–5000-5K	5,000 psi	6,500 psi
C-5000-L-7.5K	7,500 psi	10,000 psi
C–5000-10K	10,000 psi	12,500 psi
C–5000-L-10K	10,000 psi	12,500 psi
C-5000-20K	20,000 psi	25,000 psi

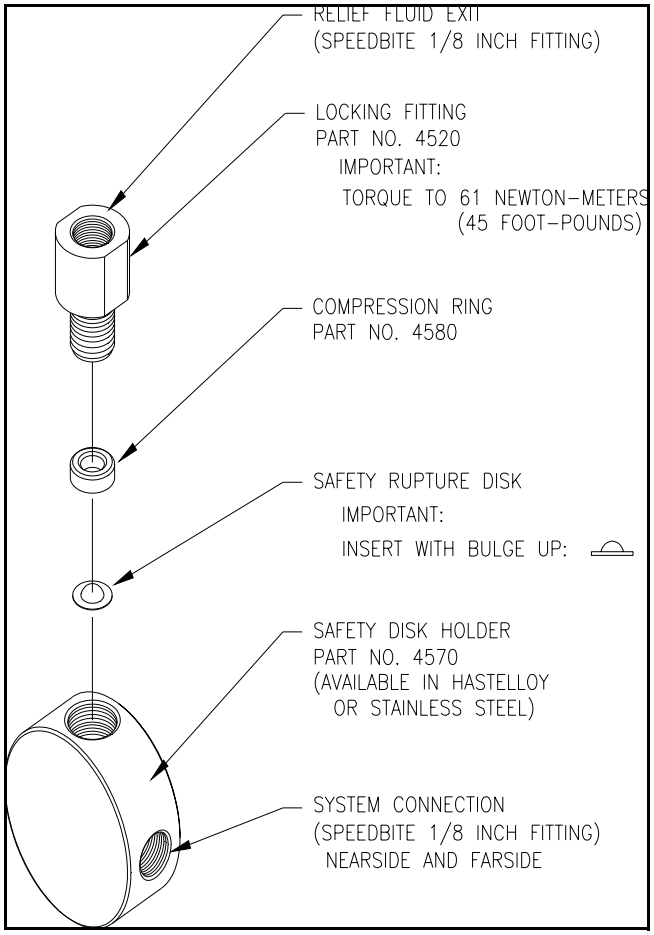

Figure 5-1 Safety Rupture Disk Assembly

5.3.4.1 Safety Rupture Disk Holder (All C-5000 Pump Cylinder models except C-5000-20K)

For systems rated at 10,000 psi or less, the safety rupture disk holder, shown in Figure 5-1, is a round metal component that is installed between the valve and the pump cylinder. The safety rupture disk holder has reversible inlet and outlet openings that use Autoclave W125 (1/8" speedbite) fittings. Located inside the holder is a Fike 3/16" rupture disk that is held in place by a compression ring and locking fitting, which is connected to the port on the bottom of the holder. If the specified pressure is exceeded, the safety rupture disk bursts and fluid is expelled through the relief fluid exit. The fluid exit port is also fitted with an Autoclave W125 (1/8" speedbite) fitting, so that tubing can be attached to vent fluid to a harmless location.

5.3.4.2 Safety Rupture Disk Holder (C-5000-20K Pump Cylinder models)

For C–5000-20K systems, the safety rupture disk holder is a 1/4" high pressure male inlet safety head. The holder is connected to the plumbing "cross" which is then attached to the pump cylinder. If the specified pressure is exceeded, the rupture disk bursts and fluid is expelled through the relief fluid exit. The relief fluid exit is a 3/8" NPT fitting, which can be easily adapted so that tubing can vent fluid to a harmless location. To achieve a good seal, Quizix recommends that 120 ft–lbs (160 Newton meters) be used to torque down a replacement disk rated for 25,000 psi.

5.3.4.3 All C-5000 Pump Cylinder Models

For all pump systems, each safety rupture disk is shipped with a tag that shows the specified pressure level at which it will activate and a torque specification. To operate properly, the retaining fitting must be torqued to the level shown on the tag (for a 12,500 psi disk, the torque is specified at 45 foot/pounds). If you unscrew the locking fitting in the vent port, make sure to screw it back to the specified torque level.

Safety rupture disk holders are available in either stainless steel or Hastelloy. If you have purchased a system with the Hastelloy option, then a Hastelloy safety rupture disk holder is provided. Also, safety rupture disk holders may be placed in an oven for high temperature pump systems.

If you regularly operate your pump system at pressures in the range of 80% to 100% of maximum pressure (8,000–10,000 psi for a standard SP-5200-10K system), note that rupture disks can weaken after extended use at these pressures. If you frequently operate at such high pressures, you should replace the rupture disks on a regular basis as part of their scheduled system maintenance. Alternatively, you may want to install rupture disks with a higher rating. In that case, contact Quizix for the appropriate specifications.

The rupture disk included in all Quizix pump systems is a "one–time only" item that must be replaced after it is activated. It is not a pressure relief valve and cannot be tested. If you bring the system pressure up to the level at which the disk is designed to activate, it breaks and must be replaced.To replace a safety rupture disk, carefully follow the instructions in Chapter 11.

5.4 Emergency Stop Capability

The CMD-5000 Dual Controller Driver includes an emergency stop capability, which is accessed through the User Interface connector. If you would like to implement an emergency stop function for your pump system, you will need to install a User Interface cable.

Pin 19 of the user interface connector is tied to the emergency stop signal of the pump controller. By setting a jumper inside the controller, this line can be made to be: 1) a pull to ground for emergency stop, or 2) a loop signal which, if it is interrupted, causes an emergency stop. For more information, see Appendix B of the PumpWorks User's Manual.

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6 CMD-5000 DUAL CONTROLLER DRIVER

The CMD-5000 Dual Controller Driver is included in all 5000 Series Pump Systems and operates with C-5000 pump cylinders. The CMD-5000 (CMD stands for **C**ontroller **M**otor **D**river) contains two primary subcomponents:

1. The pump controller, which controls the operation of the entire 5000 Series Pump System. The pump controller operates the pump system according to the settings made in PumpWorks. It coordinates all system components and maintains the safety and integrity of the pump system.
2. The motor driver provides the drive for the stepper motors attached to the C-5000 pump cylinders. The motor driver converts the pulse and directional signals from the pump controller to high current motor drive signals.

The CMD-5000 Dual Controller Driver is a 2-channel unit and can control two C-5000 pump cylinders. Pump systems with three or four pump cylinders will include two CMD-5000's. Pump systems with five or six pump cylinders will include three CMD-5000's.

The CMD-5000 Dual Controller Driver measures approximately 30 x 19 x 13 centimeters (approximately 12 x 7-1/2 x 5 inches). It must be used with a Serial Expander/Isolator, which is also discussed in this chapter. For simplicity, the CMD-5000 Dual Controller Driver is often referred to as the "pump controller" in this manual.

6.1 The Pump Controller Subcomponent

The pump controller portion of the CMD-5000 is the "brains" of the entire pump system. It performs the following specific functions:

- Controls pump cylinders through real–time control of the rate and direction of the stepper motors.
- Controls the operation of the valves.
- Monitors fluid pressure, as measured by the pressure transducers.
- Monitors safety shutdowns, such as when a safety pressure error occurs.
- Monitors the fluid volume and position of the piston in each pump cylinder.
- Monitors system status, such as cable connections, power turned on, etc.
- Monitors any analog signal inputs that may be added to the pump system, such as other pressures or temperatures.
- Communicates with PumpWorks to translate user commands into actual pump operation.
- Transfers system data back to PumpWorks for viewing and, if desired, recording data in a software data log.
- Provides signal conditioning for analog transducers so that they can be calibrated.

- Executes rate ramping and valve operations during switch–over from one pump cylinder to another.
- When required, executes pressure control algorithms, to maintain a specified pressure level.

6.2 Motor Driver Subcomponent

The motor driver portion of the CMD-5000 Dual Controller Driver provides the drive for the stepper motors attached to the C-5000 pump cylinders. The motor driver runs at an extremely high number of steps per motor revolution, which permits the excellent flow rate resolution of the 5000 Series pump systems. For example, the C-5000-10K pump cylinder has a flow rate resolution of 0.00000078 ml per minute (0.78 nanoliters per minute), which represents the amount of fluid delivered with one step of the motor driver.

A heat sink is located on top of the CMD-5000, which is used to carry excess heat away from the motor driver. The CMD-5000 also includes a thermostatically-controlled fan. When the fan is on, you will be able to feel air flow across the top of the heat sink. You will also be able to hear the sound of the fan located inside the CMD-5000. Because the fan is thermostatically controlled, it turns off automatically when air is not required for cooling, resulting in quieter operation.

The air holes on the bottom of the CMD-5000 provide the air intake for the fan. **Both the heat sink and the air holes must have access to fresh, room-temperature air.** Do NOT put a CMD-5000 Dual Controller Driver into an oven.

6.3 On/Off Switch, Power Cord, and Fuse Holder

The On/Off switch is a small black rocker switch on the back side of the controller, next to the power cord. Press it to turn on the CMD-5000. When the CMD-5000 is turned on, a sequence of diagnostic tests is run, as shown on the two-digit display labeled “Pump Number.”

In general, the user should install all cable connections and have PumpWorks running on their computer BEFORE turning on the controller. Watch the two-digit display when the controller is turned on; see Section 6.5 for important information on this feature.

WARNING
THE PUMP CONTROLLER SHOULD BE TURNED OFF BEFORE CONNECTING OR DISCONNECTING ANY OF THE CABLES.

A modular power cord receptacle is next to the on/off switch. The power cord should be connected to an AC power outlet, preferably by way of an Uninterruptable Power Supply (see Chapter 10 on Uninterruptable Power Supplies for more details). The power cord

supplied is compatible with the voltage and style of plug used in the country to which the pump is shipped.

A fuse box is located next to the power cord connector and includes either a fuse for 120 volt or 220-240 volt operation. To change the fuse, simply pop out the fuse holder and replace the fuse. Use a fuse with a rating appropriate to the voltage you are using (1.5 amps for 120 volts; 0.75 amps for 240 volts).

Your CMD-5000 Dual Controller Driver has been set up to use either 120 or 240 volt power, depending on the standard voltage in your country. To change from one voltage to another, see the instructions in Chapter 10.

6.4 Cable Connections

6.4.1 Sensor Cable

The Sensor Cable connects the CMD-5000 Dual Controller Driver with the sensor board on each C-5000 pump cylinder. The purpose of the sensor board is to detect the position of the piston within the cylinder barrel. Each pump controller includes two 15-pin, D-style, connectors for the sensor cables, labeled “Sensor Cable” for Cylinder A and Cylinder B. If the pump controller is used with only one pump cylinder, the connector for Cylinder B will not be used.

6.4.2 Motor Cable

The Motor Cable connects the CMD-5000 Dual Controller Driver with the stepper motor attached to each C-5000 pump cylinder. Each pump controller includes two 9-pin, D-style connectors for motor cables, labeled “Motor Cable” for Cylinder A and Cylinder B. If the pump controller is used with only one pump cylinder, the connector for Cylinder B will not be used.

6.4.3 Transducer and Valve Cable

The Transducer and Valve Cable connects the CMD-5000 Dual Controller Driver with both the pressure transducers and the pilot solenoids for the valves. This cable has a 25-pin, D-style connector at the pump controller end, and branches out into one cable branch for each pressure transducer and one cable branch for each pilot solenoid. There is a 6-pin circular connector at the pressure transducer end for each branch. The branches are labeled “Transducer 1A” and “Transducer 1B”. If there are two controllers, the branches on the second controller will read “Transducer 2A” and “Transducer 2B”.

This cable also branches into wires that are connected to the pilot solenoids with 2-pin connectors. The wires are numbered and must be connected in the proper order; for example, wire 1 into pilot solenoid 1, wire 2 into pilot solenoid 2, and so on.

6.4.4 Data Link Cable

The Data Link Cable connects the CMD-5000 Dual Controller Driver with the Serial Expander/Isolator. The CMD-5000 for Cylinders 1A and 1B should be plugged into Port A. If your system includes two pump controllers, the data link cable for the second pump

controller should be connected to Port B. The Data Link Cable has RJ-22 connectors (phone handset-type connectors) at both ends.

6.4.5 Front Panel Cable

The Front Panel Cable connects the CMD-5000 with the Front Panel, which may be used instead of PumpWorks to control the pump system. It is not available at this time.

6.4.6 User Interface Cable

The optional User Interface Cable allows the 5000 Series Pump System to connect to various external devices, which a user may wish to add. Additional sensors, valves, digitally controlled devices and logic inputs, as well as power, are available on this 37-pin D-style connector. By connecting any such additional valves, digital inputs, or analog inputs (such as additional temperature or pressure transducer readings) to the CMD-5000, the user will have access to them from PumpWorks. The User Interface Connector also includes an emergency stop control signal for users who want to implement an emergency stop capability for their pump system. See Appendix B of the PumpWorks User's Manual for more information on the User Interface Cable.

If you have a recirculating pump system, a User Interface Cable will be included with your system and will be labeled "Recirculating Cable." It is used to establish communications between the controllers in recirculating systems.

6.4.7 AC Power Cord Receptacle

The AC power cord receptacle is located next to the on/off switch. The power cord supplied will agree with the voltage used in the country the pump was shipped to. The power cord should be connected to an AC power outlet, preferably by way of an uninterruptable power supply. See Chapter 10 for more information about uninterruptable power supplies.

6.4.8 RS-232 Cable

The RS-232 Cable connects the Serial Expander/Isolator with the computer. This cable has a 9-pin, D-style connector at both ends. The male end connects to the Serial Expander/Isolator port; the female end connects to one of the serial ports on the computer. You can use any serial port on your computer, but must specify which port you selected in the system communications using the Configure Pump Communications window in PumpWorks. When shipped, PumpWorks is configured for the serial expander/isolator to connect to serial port 1.

6.5 Pump Number (Two-Digit Display)

Under the label "Pump Number" is a two-digit display, which allows the pump controller to communicate information to the user. Using letters, numbers, or a combination of the two, the two-digit display can convey overpressure or underpressure errors, communication errors, driver errors, or the absence of a cable. If no errors are present, the two-digit display will show the pump number (1, 2, 3, and so on). The pump number is assigned by PumpWorks based on the first available screen position, starting from left to right, on PumpWorks main window.

When turning on the pump controller, the user needs to watch the two-digit display. The first thing the user will see when the CMD-5000 is turned on is all segments of the display will light at once, briefly. Next the display will flash the boot version number (currently version 3.6).

The basic pump controller diagnostics are performed next. Refer to Figures 6-1 and 6-2. The right hand digit will light, the left hand digit will not. One segment of the right hand digit will light at a time, starting with the top segment as shown in Figure 6-1. One segment lights, then a second segment lights, then a third, and so on.

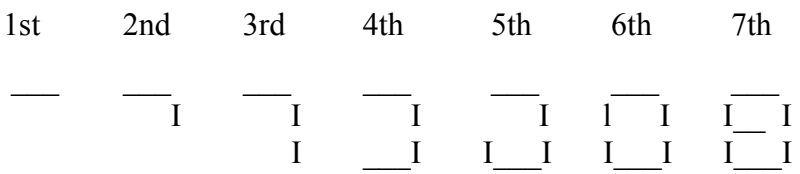

Figure 6-1

Each segment that lights is a confirmation that a specific aspect of the pump controller is operating correctly.

Segment 1: RAM test OK

Segment 2: move code OK

Segment 3: Boot CRC OK

Segment 4: Block 1 CRC check

Segment 5: Block 2 CRC check

Segment 6: Block 3 CRC check

Code CRC OK, Jump to program

The pump controller software initialization is performed next. The left hand digit will light, the right hand digit will not. The left hand digit will display number 1, then 2, then 3, then 4, then 5, then 6, then 7. Each number that lights is a confirmation that a pump controller software function is operating correctly. The numbers will flash quickly.

The numbers on the left hand digit represent the following tests performed by the controller's software:

0,1,2 = load program into RAM and initialize variables

3,4 = calibrate pressure channel A to D for pump cylinders A and B

5,6 = check and set pump cylinder location for pump cylinders A and B

7 = all tests passed, accept commands from PumpWorks

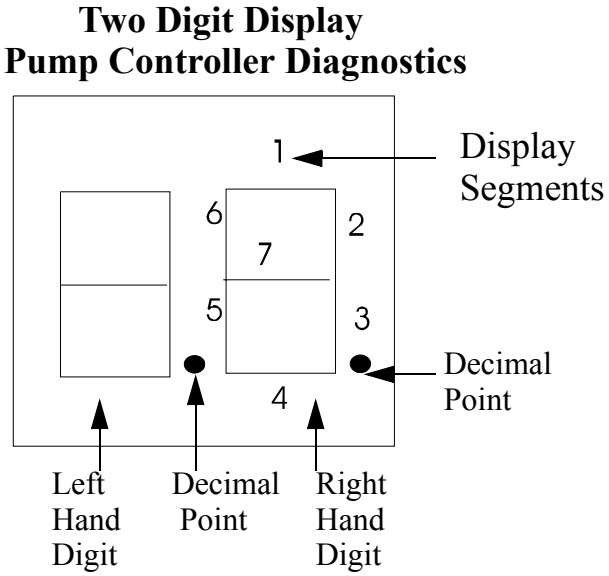

Figure 6-2

In the final step, "do" will flash alternately with "0". The "do" stands for digital overpressure. As a safety precaution, each time a pump is powered on, the safety pressure is set at -50 PSI. The user must set the safety pressure to a valid operating value each time the pump is powered up. The "0" means the pump has not yet been assigned a pump number by PumpWorks. As soon as the pump is installed onto PumpWorks, the "0" will be replaced with the pump number.

When PumpWorks and the pump controller are communicating with each other, decimal points on the two-digit display will flash. A decimal point will flash on the right side of the right digit, which means the pump controller is sending communications to PumpWorks. A decimal point will flash on the right side of the left digit, which means that PumpWorks is sending communications to the pump controller. The right digit decimal point will flash brighter than the left digit decimal point because the pump controller has more data to send to PumpWorks than the amount of data PumpWorks has to send to the pump controller.

Refer to Chapter 12, Section 12.3.3 for more information regarding the two-digit display. Included you will find a list of error messages and how to correct them.

6.6 Serial Expander/Isolator

The Serial Expander/Isolator (see Figure 6-3) is a device which takes one serial port of a computer and expands it into four data ports.

The serial expander/isolator is important for two main reasons. First, since computers come with a limited number of serial ports, the serial expander/isolator allows up to four CMD-

5000 Dual Controller Drivers to be connected to a single computer serial port. Therefore, one computer serial port, with one serial expander/isolator connected to it, can operate up to eight C-5000 pump cylinders (or a combination of C-5000, C-6000 and QX Series pumps).

The serial expander/isolator also serves a second purpose: it provides electrical isolation between the computer running PumpWorks and the C-5000 Pump Cylinders. The RS-232 data signals from the computer are optically isolated via an opto-coupler from the electrical data signals of the CMD-5000. Thus, each pump cylinder is electrically isolated from the computer and from every other pump cylinder.

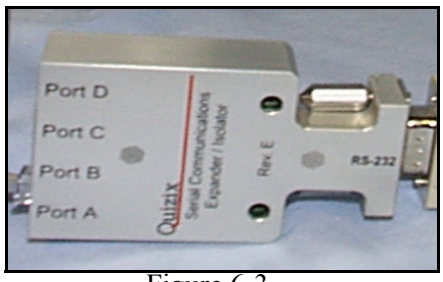

Figure 6-3

This isolation is provided to prevent ground loops and system grounding problems when the CMD-5000 unit(s) and computer are plugged into different power circuits. It is not designed to protect against incorrectly wired AC power circuits.

6.7 Pump Controller Software

The CMD-5000 Dual Controller Driver contains no user-serviceable parts. The user should NOT open a pump controller and attempt to service it. The Troubleshooting chapter of this manual provides details on diagnosing and resolving problems safely. If your CMD-5000 is malfunctioning, it must be returned to Quizix for service.

The operation of the 5000 Series Pump System is controlled by two separate software programs:

- PumpWorks, which is stored on the user's computer, and
- The pump controller software, which is stored in the CMD-5000.

New versions of both software programs are periodically released by Quizix. Problems detected after a software version is released are resolved in later versions.

In order to update the pump controller software, it is NOT necessary to open the CMD-5000. New versions of the pump controller software can be downloaded directly to your pump controller via PumpWorks. See Section 12.8, "Update Pump Controller Software" in the PumpWorks User's Manual for more information. New versions of the pump controller software can be downloaded directly from the Quizix website at www.Quizix.com.

The controller software version number is shown in "About PumpWorks for Windows" under the PumpWorks Help menu. If you update your controller software, the new version number will appear in that window.

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7 PUMP CYLINDER

This chapter describes the 5000 Series Pump Cylinder, also called the C-5000 Pump Cylinder. Included are the following sections:

- Quizix C-5000 Pump Cylinder, Section 7.1
- Important Operating Notes, Section 7.2
- Primary Mechanical Subcomponents of the Pump Cylinder, Section 7.3
- Cylinder Barrel and Seal Assembly, Section 7.4
- Pump Cylinder Sensor Board, Section 7.5
- Pump Cylinder Base Plate, Section 7.6
- Hastelloy Option for Corrosive Fluids, Section 7.7
- Pump Cylinder High Temperature Option, Section 7.8
- Pump Cylinders with Optional Wash Ring, Section 7.9

7.1 Quizix C-5000 Pump Cylinder

All Quizix 5000 Series pump cylinders are stepper motor–driven, positive–displacement pumps with precision ball screws. The basic operation of the pump cylinder is as follows:

- When the piston retracts out of the cylinder barrel, fluid is pulled into the cylinder barrel through the fill side of the valve.
- When the piston extends into the cylinder barrel, fluid is pushed out of the cylinder barrel through the deliver side of the valve.
- With both sides of the valve closed, the piston extends slightly and pre-pressurizes the fluid within the cylinder barrel.

These operations can be performed independently with the user opening and closing the valves, setting the cylinder direction and then starting the pump. In most applications, however, the user chooses to have PumpWorks operate the cylinders automatically so that each cylinder barrel fills and empties continuously.

The 5000 Series Pump System is designed to include anywhere from one to eight pump cylinders. Continuous fluid flow requires two pump cylinders per fluid. Working as a coordinated pair, one pump cylinder (the active cylinder) pumps fluid while the other pump cylinder (the standby cylinder) fills and pre-pressurizes. When the first cylinder is empty, they switch and the second cylinder becomes the active cylinder and pumps out its fluid. Operated in this manner, the pair of cylinders can pump continuously for any length of time. For this reason, most users have two pump cylinders (for continuous flow of one fluid) or four cylinders (for continuous flow of two fluids).

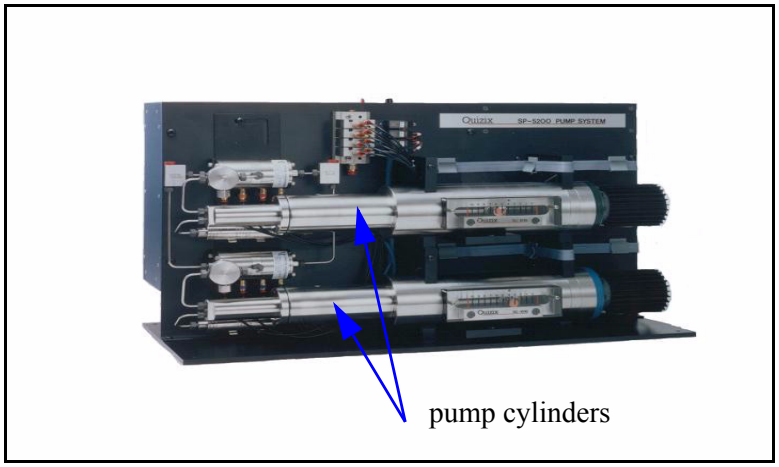

Figure 7-1 SP-5200 Pump System

The following three options are available for the 5000 Series pump cylinder.

- Hastelloy (C-276) wetted parts are available and recommended for users who pump highly corrosive fluids.
- A high temperature option permits users to heat the pump cylinder, so that the fluid delivered is at reservoir temperatures. This option allows temperatures of up to 160°C to be maintained within the pump. See Section 7.8 for more information about the high temperature option.
- An optional wash area is available to wash highly corrosive fluids off of the piston as it retracts. For more information refer to Section 7.9.

There are six models of 5000 Series pump cylinders available. Of the six models, the C–5000-10K is the most popular. It provides a maximum pumping rate of 15 ml per minute, with a maximum pressure of 10,000 psi, and a stroke volume of 9.3 ml. It has a piston diameter of 1/2 inch. Five other models are available for users with different requirements, as shown in Table 7-1

.

Table 7-1 The 5000 Series Pump Cylinders

Model	Maximum Pressure	Maximum Flow Rate	Cylinder Barrel Volume	Piston Diameter
C–5000-2.5K	2,500 psi	60 ml per minute	37 ml	1.00 inch
C–5000-5K	5,000 psi	30 ml per minute	21 ml	.750 inch
C–5000-L-7.5K	7,500 psi	3.75 ml per minute	21 ml	.750 inch
C–5000-10K	10,000 psi	15 ml per minute	9.3 ml	.500 inch
C–5000-L-10K	10,000 psi	2.0 ml per minute	9.3 ml	.500 inch
C–5000-20K	20,000 psi	7.5 ml per minute	5.2 ml	.375 inch

The two “L” models are designed for applications which require extremely low flow rates.They use a different ball screw pitch and different motor resolution. For example, the flow rate resolution of the C-5000-10K is 0.00000078 ml/minute (0.78 nanoliters/minute); the flow rate resolution of the C-5000-L-10K is 0.00000031 ml/minute (0.31 nanoliters per minute).

All C–5000 pump cylinders have the same basic design. Only the piston diameter and size of the cylinder barrel are changed between models (plus the ball screw pitch and motor resolution in the “L” models). Thus, all the information in this chapter applies to any of the C–5000 pump cylinder models manufactured by Quizix. Figure 7-2 shows a simplified drawing of an ambient temperature C-5000 pump cylinder.

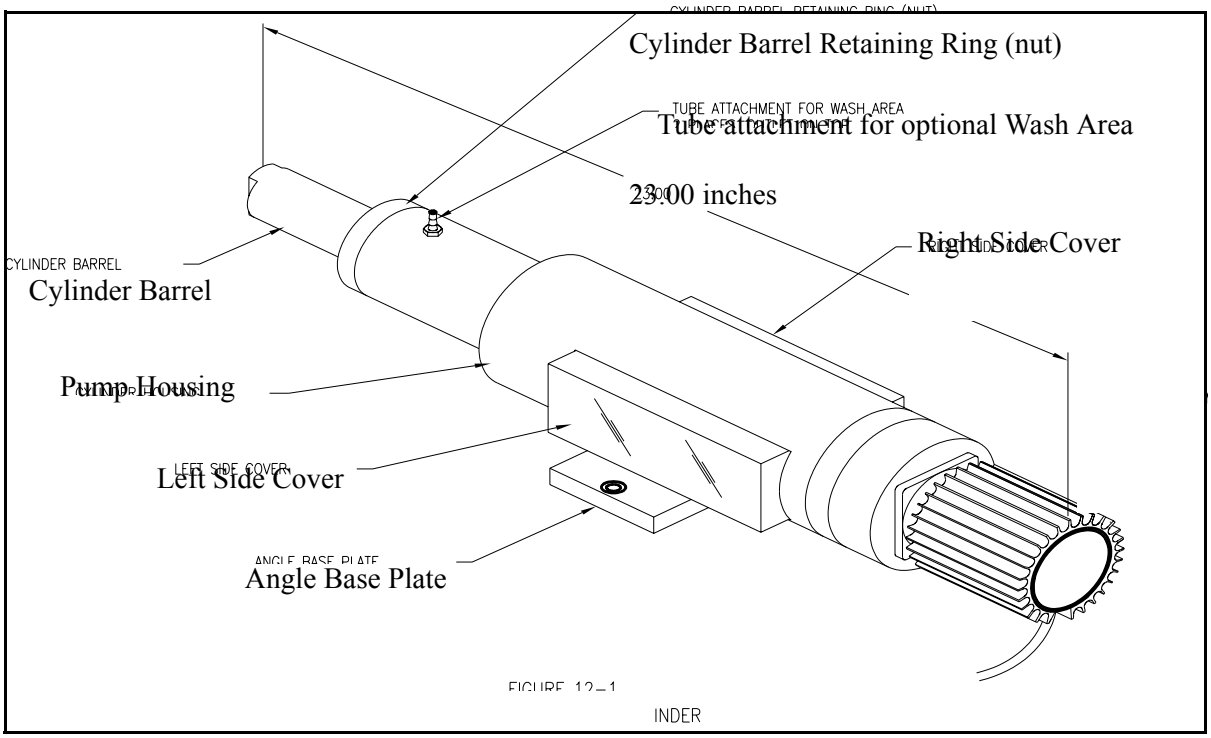

Figure 7-2 C-5000 Ambient Temperature Pump Cylinder

7.2 Important Operating Notes

This section lists important operating notes for the C–5000 pump cylinders.

1. Operation at Low Pressures

The C–5000-10K pump cylinder is designed for high pressure operation and uses pressure transducers that operate up to 10,000 psi. All of the 5000 Series models are shipped with pressure transducers that correspond to their respective maximum pressure ratings. If any of the pump cylinders (except the C–5000-2.5K) are operated at less than 100 psi, the system does not perform optimally. If you plan to operate the system at very low pressures, such as less than 100 psi, contact Quizix to obtain pressure transducers which are more effective at lower pressures.

2. **Orientation of the Pump Cylinder**

   The pump cylinder is designed to operate horizontally. It may malfunction if mounted in a vertical position. There is a slight upward slant to the cylinder so that the barrel is not perfectly horizontal. The outer end of the cylinder barrel (where the plumbing is attached) is its highest point, so that trapped gas can be expelled through the plumbing. The base plate, to which the cylinder is bolted, places the cylinder in the proper orientation with a slight upward tilt.

7.3 Primary Mechanical Subcomponents of the Pump Cylinder

Starting at the motor end of the pump cylinder, the following five subcomponents comprise the basic "drive train" of the C-5000 pump cylinder.

7.3.1 Stepper Motor

The motor attached to the pump cylinder is a stepper motor, which rotates in the direction and at the speed dictated by the CMD–5000 Dual Controller Driver. A heat sink is attached to the motor to provide adequate cooling. High temperature versions of the pump cylinder also have a fan attached to the motor.

7.3.2 Harmonic Drive

The harmonic drive gear reduction assembly uses a 100:1 ratio. The output of the harmonic drive rotates once for every 100 revolutions of the stepper motor and turns the ball screw.

7.3.3 Ball Screw and Ball Nut

The ball screw and ball nut convert the rotary motion of the motor and harmonic drive into linear motion. The ball nut moves back and forth on the ball screw as the ball screw rotates. Two versions of ball screws are used. One has a pitch of 0.5 inches, and the other, which is used on the two "L" models, has a 0.2 inch pitch.

7.3.4 Ball Nut Assembly

Attached to the ball nut is a ball nut assembly, where the piston is screwed in. Rollers and side rails are used to counteract the torque.

7.3.5 Piston and Cylinder Barrel

The piston screws into the ball nut assembly so that it can be replaced easily. The piston moves back and forth in the cylinder barrel following the motion of the ball nut. The piston is made of highly polished silicon carbide, which is extremely corrosion and scratch resistant.

CAUTION
The piston is quite brittle, and therefore should never be dropped or handled roughly.

When the stepper motor rotates in a clockwise direction, the piston retracts and the cylinder barrel fills with fluid (assuming the fill valve is open and the deliver valve is closed). When the motor reverses direction, the piston extends and the pump delivers fluid (assuming the deliver valve is open and the fill valve is closed). Fluid is brought to pressure when both valves are closed and the piston extends to compress the fluid. When the piston is maintaining a specific pressure, the motion is referred to as "Servo" in the PumpWorks software.

In addition to the five primary parts described above, the following parts are necessary to properly direct and contain the mechanical forces of the cylinder "drive train".

7.3.6 Bearings

The pump cylinder contains both radial bearings and a thrust bearing that secure the ball screw in place.

7.3.7 Side Rails and Rollers

The side rails and rollers transfer the torque from the ball nut, so that the ball nut does not spin and slide down the ball screw when fluid in the cylinder barrel is at high pressure. The torque is transferred from the ball nut to two rollers (one on each side), and then to the side rails, which are directly under the side covers on each side of the pump cylinder.

7.4 Cylinder Barrel and Seal Assembly

The cylinder barrel contains the fluid being pumped. There are two fittings (Autoclave 1/8–inch AE speedbite W 125) on the end of the cylinder barrel. Tubing that connects to the valves should be inserted into the upper speedbite fitting; this tubing serves as the inlet and outlet of the pump cylinder. Tubing from the pressure transducer should be connected to the lower fitting, so that the transducer can monitor pressure inside the cylinder barrel.

The C–5000-20K pump cylinder has only one fitting at the end of the cylinder barrel, which is an Autoclave F250C. This fitting connects to a cross, which then connects to the pressure transducer and safety rupture disk assembly.

The fluid is held in the cylinder barrel by a seal. Ambient temperature versions of the C–5000 pump cylinder use a seal constructed of ultra high molecular weight polyethylene (UHMW-PE), which is a soft plastic. High temperature versions of the pump contain seals made of Aflas® or sometimes PTFE, which is a type of Teflon®. Tests have shown that the seals used in the Quizix pump are leak–free for long periods of use.

CAUTION
The seals can easily scratch and must be handled with extreme care during insertion.

The ambient temperature seal assembly is shown in Figure 7-3. The back–up ring serves two functions; it supports the seal and it guides the piston. Because the seal has no structural strength, it is supported by the back–up ring, which holds the seal in the seal cavity. The seal and back-up ring are held in place by a seal retaining nut.

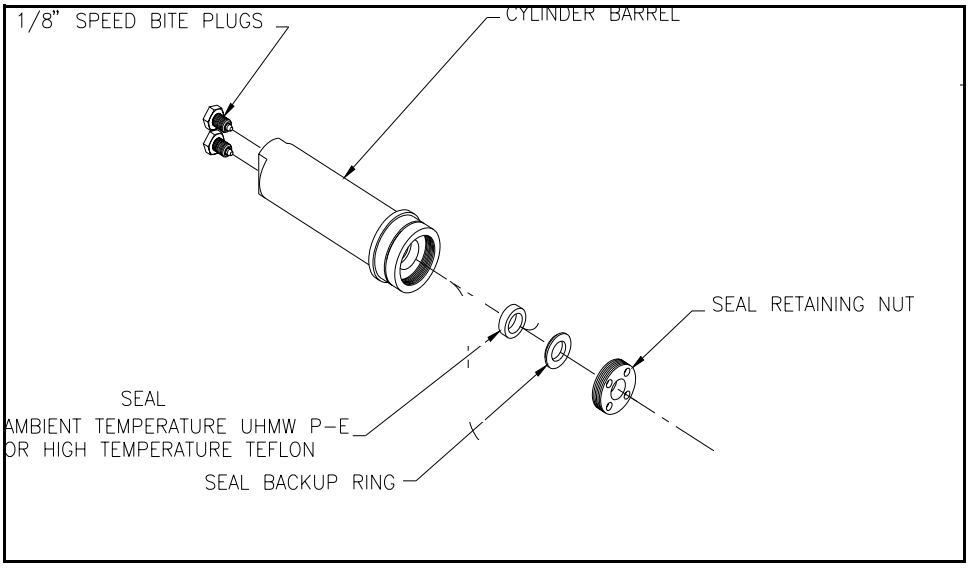

Figure 7-3 Ambient Temperature Seal Assembly

The size of the seal and the back-up ring are determined by the size of the piston. C-5000-10K pump cylinders have pistons which are 1/2 inch, so the seals are also 1/2 inch. As shown on Table 7-1, each pump cylinder model has a different piston size, and the seals will be sized accordingly.

If the seal assembly is disassembled, be sure to keep each cylinder barrel, seal back–up ring, and piston from the same pump cylinder together as a group. For best operating results, the cylinder barrel, seal back–up ring, and piston from a pump cylinder should be re–installed into the same pump cylinder.

For instructions on how to change a seal, see Chapter 11, Section 11.2.

7.5 Pump Cylinder Sensor Board

A sensor board is located under the right side cover of the pump cylinder. This board detects the position of the piston at all times by tracking the location of the ball nut to which the piston is attached. It does this by two different sensing techniques. First, there are six microswitches that are activated by the roller, which is attached to the ball nut. As the ball

nut moves down the ball screw, each microswitch is activated in succession. Secondly, a magnet is located just behind the roller. The sensor board contains eight reeds that register as the magnet moves across them.

The piston position data gained from both the microswitches and the reeds is transferred to the CMD-5000 Dual Controller Driver through the sensor cable. The piston position is displayed on the PumpWorks main window and even more detailed information is available in the Cylinder Switch Status window.

Ambient temperature versions of the pump cylinder have clear plastic side covers so that the position of the roller can also be monitored visually. The side covers are marked with a scale from 1 to 10, indicating the full range of the piston's motion in milliliters. The roller can be used as an indicator of the piston's position.

High temperature versions of the pump cylinder have an aluminum cover with a slot cut into it for viewing the roller position.

7.6 Pump Cylinder Base Plate

The pump cylinder is mounted to a base plate with four bolts. The base plate has a slight slant to it (about 1 degree), so that the cylinder is tilted upward when it is mounted. This upward tilt permits trapped gas to escape from the cylinder barrel through the uppermost hole at the end of the barrel to which the valve tubing is attached.

7.7 Hastelloy Option for Corrosive Fluids

The most popular pump cylinder model, the C-5000-10K, is available with either stainless steel (SS-316) or Hastelloy (C-276) wetted parts. In the other C-5000 models, Hastelloy is standard. In Hastelloy pump cylinders, all metal parts that come in contact with the pumped fluid are constructed of Hastelloy C–276. Hastelloy is highly corrosion resistant and will extend the life of the pump substantially if you are pumping highly corrosive fluids.

7.8 Pump Cylinder High Temperature Option

The C-5000 pump cylinder is available in a high temperature version that allows the cylinder to be heated to 160°C. The high temperature version of the C–5000-10K cylinder is shown in Figure 7.4. The following lists the changes made to the high temperature version of the C-5000-10K pump cylinder.

- The pump cylinder includes a motor extension, which is a 6" extension between the cylinder housing and the motor. The entire pump cylinder housing and cylinder barrel can be placed inside an oven. The motor extension provides a place for the oven wall to touch the cylinder so that the entire housing is inside the oven, while the motor and harmonic drive protrudes outside the oven wall. Generally, a hole is cut in the oven wall where the motor extension is located, so the wall intersects the pump cylinder at the extension. Refer to Chapter 1, Figure 1-2.

- A fan assembly is attached to the stepper motor to prevent overheating of the motor. The fan operates when the CMD-5000 is on and should have access to air at all times.
- The side covers are made of aluminum, not plastic.
- The seal is made of Aflas, or sometimes PTFE (teflon), not UHMW polyethylene. The high temperature seal assembly contains more parts than the ambient temperature seal assembly. (Refer to Figure 7-5)
- A different grease is used to lubricate moving parts.
- A different CAM Roller is used.

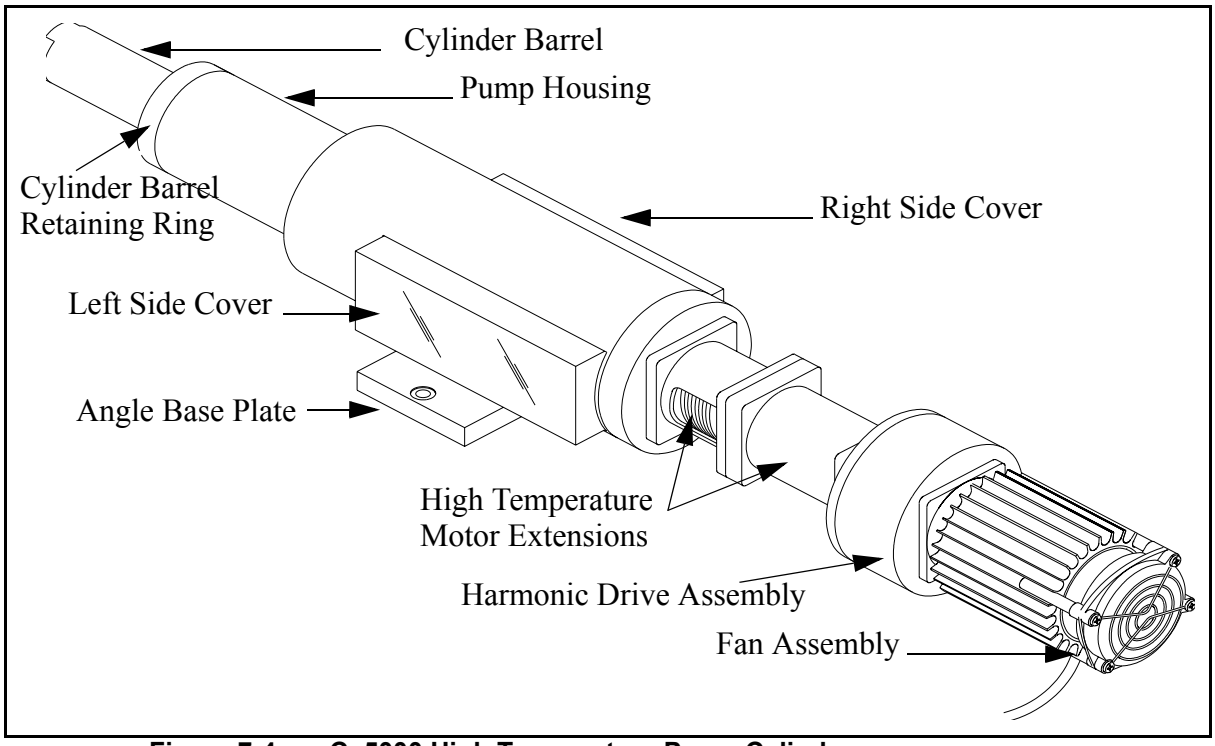

Figure 7-4 C–5000 High Temperature Pump Cylinder

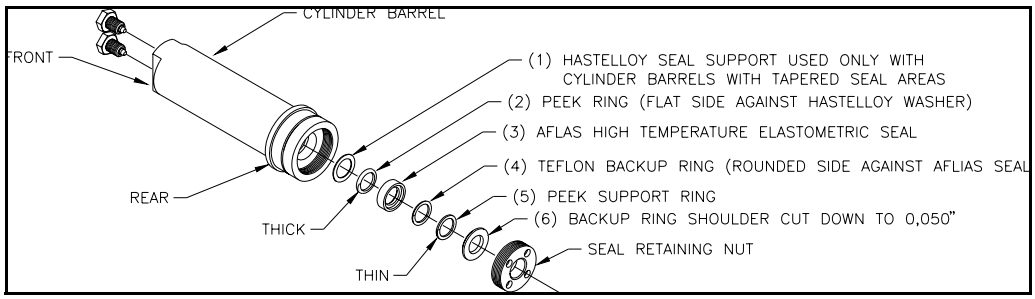
CYLINDER BARREL
FRONT
(1) HASTELLOY SEAL SUPPORT USED ONLY WITH CYLINDER BARRELS WITH TAPERED SEAL AREAS
(2) PEEK RING (FLAT SIDE AGAINST HASTELLOY WASHER)
(3) AFLAS HIGH TEMPERATURE ELASTOMETRIC SEAL
(4) TEFLON BACKUP RING (ROUNDED SIDE AGAINST AFLIAS SEAL
REAR
(5) PEEK SUPPORT RING
THICK
(6) BACKUP RING SHOULDER CUT DOWN TO 0,050"
SEAL RETAINING NUT
THIN

Figure 7-5 High Temperature Seal Assembly

7.9 Pump Cylinders with Optional Wash Ring

On most versions of Quizix C-5000 pump cylinders, the seal retaining nut is a conventional nut that does not include a wash area. However, a special version of the pump cylinder in which the seal retaining nut is incorporated with a wash ring can be ordered on model C-5000-10K. This is screwed into and out of the cylinder barrel in the same way as a normal retaining nut. When internal and external o–rings are added to this wash ring, a chamber is formed called the wash area, as shown in Figure 7-6 below.The wash area allows residue to be washed off the piston to prevent a buildup of corrosive residue.

Wash areas are not necessary except in special circumstances, such as when very corrosive fluids are pumped. Wash areas are NOT normally needed for pumping brine.

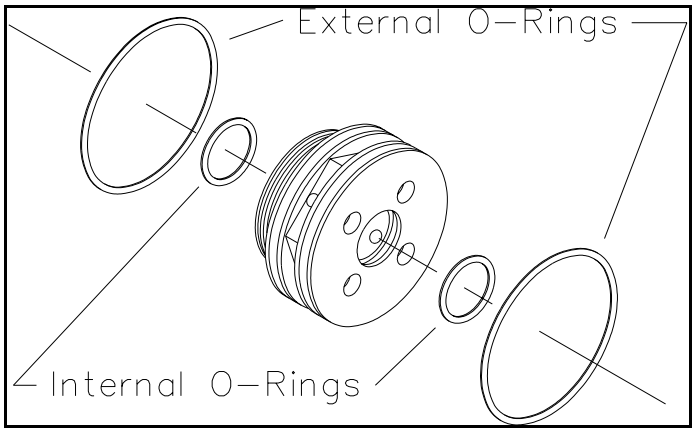

Figure 7-6 Wash Ring Option

Holes with fittings are located on the top and bottom of the pump cylinder for fluid to flush through the wash area. When installing plumbing to these holes, the fitting on the bottom of the pump cylinder should be used as the fluid inlet and the fitting on the top should be used as the fluid outlet so that trapped gas can escape.

An active wash area is one where both pairs of o-rings are installed and fluid is used regularly to rinse the piston. An inactive wash area is one without the internal and external o-rings. Do not leave any of the o-rings in the wash ring if the pump system is used without any fluid circulating through the wash area and around the piston. This situation will cause the o-rings to abrade, creating debris that can cause seal leakage. If your C-5000-10K Pump Cylinder includes a wash area option, your Spare Parts Kit will also include replacement o-rings (Refer to Table 7-2)

Table 7-2 Spare Parts Kit (Wash Ring Option)	
Item No.	**Spare Part**
1	Pointed wooden sticks. These sticks are used to remove the o–rings that are located in the wash ring. When extracting o–rings, these sticks prevent scratching the o–ring sealing area of the wash ring. **Never use a metal tool to extract the o–rings!**
2	Spare wash ring internal o–rings (2 each)
3	Spare wash ring external o–rings (2 each)

8 VALVES, TRANSDUCERS AND PLUMBING

This chapter describes the following components of a 5000 Series Pump System:

- Valves, Section 8.1
- Pilot Solenoids, Section 8.2
- Air Supply, Section 8.3
- Pressure Transducers, Section 8.4
- Fluid Plumbing, Section 8.5
- Safety Rupture Disks, Section 8.6
- Hastelloy Option for Corrosive Fluids, Section 8.7
- High Temperature Option, Section 8.8

8.1 Valves

Quizix uses constant–volume, air–actuated valves manufactured by Vindum Engineering. All pump systems with 5000 Series pump cylinders (except model C-5000-20K) use CV–310 valves. These valves are rated at 10,000 psi. Systems with C–5000-20K pump cylinders typically use CV–320 valves, which are rated up to 20,000 psi.

There is usually one valve per pump cylinder in a pump system, although some 3–cylinder systems may use only two valves. A high temperature option allows valves to be heated to 160°C.

The valves use a 3–way, T–formation design, so that there are two internal valves, or gates, that control the flow of fluid into and out of the pump cylinder. That is, each CV-310 valve includes both a fill valve that controls the flow of fluid into the pump cylinder and a deliver valve that controls the flow of fluid out of the pump cylinder. The CV-310 valve has an inlet tube at the fill side, an outlet tube at the deliver side, and a tube that leads to the pump cylinder in the center (See Figure 8-1).

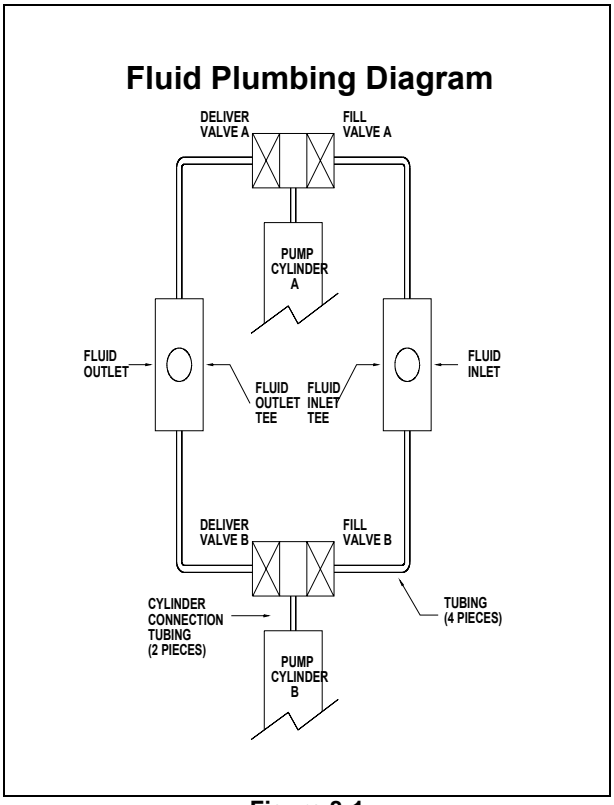

Figure 8-1

For fluid to flow into the pump cylinder, the fill valve must be open and the deliver valve must be closed. The fluid then flows into the valve through the opened fill valve. For fluid to flow out of the pump cylinder, the fill valve must be closed and the deliver valve must be open. The fluid is then pumped out of the pump cylinder and through the opened deliver valve and the fluid outlet tube. Both the fill valve and the deliver valve are controlled by two air tubes from a pilot solenoid. Air flows through one of the tubes to open the valve and air flows though the other tube to close the valve.

When two C-5000 pump cylinders are operated in paired mode, the valves open and close automatically, so that one pump cylinder is filling while the other is delivering fluid. The Quizix pump system is designed so that the switchover process between pump cylinders is extremely precise and a constant rate or constant pressure is maintained at all times.

During most pumping operations, the valves operate automatically, opening and closing as necessary for the operating mode that is selected. However, the PumpWorks software allows the user to control the valves individually when desired. For further information about the features and specifications of the valves, refer to the Valve User's Manual from Vindum Engineering, which was shipped with the pump system.

8.2 Pilot Solenoids

The valves used in the Quizix pump system are air–actuated and require the use of electrically–operated valve solenoids and a solenoid manifold. The valve solenoids receive

electrical signals from the CMD-5000 Dual Controller Driver and convert these signals to air pulses that open and close the fluid path in the air–actuated, constant volume valves.

The pilot solenoids are connected to the CMD-5000 with a cable called the Transducer and Valve Cable. This cable branches out at the solenoid end, providing one branch with a 2–pin connector for each solenoid. The small cable branches and solenoids are numbered so that they can be connected in the proper order, such as cable 1 into solenoid 1, etc. When moving or re-configuring the pump system, this cable should be disconnected at the pump controller end, not the pilot solenoid end.

8.3 Air Supply

The valves used by the pump system are air–actuated. Air is taken into the system at the pilot solenoid manifold, then air lines connect the pilot solenoids and the valve (Refer to Figure 8-2). Air is exhausted from the system through two outlets labeled EA and EB in the manifold.

The air inlet valve at the bottom of the manifold, labeled P, contains a 1/4–inch quick–disconnect fitting. You should insert a section of 1/4 inch tubing into this fitting to connect the system with a pressurized air source that is regulated at 75–120 psi. A standard laboratory air supply with an air compressor may be used. The air should be clean, dry, and oil–free.

The manifold supplies air to all of the pilot solenoids. Each solenoid actuates one fill or deliver valve through two air lines. Each Vindum CV valve has a fill valve and a deliver valve and thus requires a total of four air lines. The nylon tubing used as air lines to connect the pilot solenoids to the valves has a 1/8" outer diameter and is color–coded (See Figure 8-2).

Because the air supply is used only when a pilot solenoid opens or closes a valve, **the system does not require a continuous air flow.** The amount of air used by the system to switch a valve is extremely small. However, because the pilot solenoids use a small quantity of air every time the valves are switched, operation from a gas bottle is not feasible because the bottle would be emptied too quickly.

Figure 8-2 Air Connections for a 4-Cylinder System

IMPORTANT
Ensure that the air lines between the valves and the pilot solenoids are connected properly, according to the color–coded markings. For example, the brown labeled lines should connect the valve with a brown label to the pilot solenoid with a brown label. If the valves or pilot solenoids are serviced, make sure that all of the color–codes match between the valves and solenoids. See Figure 8-2. For 4–cylinder pump systems with 8 pilot solenoids and 16 air lines, each main color is used twice. The second set of pilot solenoids (numbers 5–8) contain a second black band. For example, there is a brown–labeled air tube leading to the fill portion of solenoid 1 for valve 1 and a brown **and black** labeled air tube leading to the fill portion of pilot solenoid 5 for valve 3.

8.4 Pressure Transducers

Each C-5000 pump cylinder is plumbed to a pressure transducer that measures the fluid pressure inside the cylinder barrel. The transducer converts this pressure measurement to an

electric signal, which is sent to the CMD-5000 Dual Controller Driver through a transducer cable. This cable has a 25–pin D–style connector at the pump controller end, then splits into one 6-pin circular connector for each pressure transducer.

The pressure transducers included in each system correspond to the maximum pressure of the pump cylinders in the system. For example, a SP-5200-10K pump system includes pressure transducers that are rated for 10,000 psi. An SP-5200-5K would include 5000 psi pressure transducers; an SP-5200-20K would include 20,000 psi pressure transducers.

If you plan to operate your pump system at a pressure under 500 psi, it will perform better with a pressure transducer with a lower pressure rating than the one supplied with your pump system.

The pressure transducers must be calibrated properly for the pump system to provide pulseless flow. The pressure transducers can be calibrated by using the Pressure Calibration window in PumpWorks. This window allows the user to set an offset value and a gain value for each pressure transducer. See Chapter 11 in this manual and Chapter 9 in the PumpWorks User's Manual for more information on calibration.

8.5 Fluid Plumbing

The Quizix 5000 Series pump cylinders use 1/8–inch tubing for all plumbing connections. (Quizix 6000 Series pump cylinders use 1/4–inch tubing for fluid flow sections of plumbing and 1/8–inch tubing for the pressure transducer connections.) This section describes the types of tubing that are necessary for system operation.

8.5.1 User–Supplied Tubing

For the fluid inlet, connect a section of tubing from the fluid source to the tee labeled "fluid inlet". There is one fluid inlet tee for each pair of pump cylinders. A 4–cylinder pump system has two fluid inlet tees.

For the fluid outlet, connect a section of tubing from the fluid outlet tee to the user's experiment. There is one fluid outlet tee for each pair of pump cylinders. The fluid that flows through this tubing is at the user-specified rate and/or pressure.

8.5.2 Stand–Supplied Tubing

If your pump system is mounted on a support stand, which is typically done for ambient temperature pump systems, the following plumbing connections are provided. See Figure 8-3.

- **Inlet Tee to Valve Tubing:** Two sections of tubing are used to connect the fluid inlet tee to the "fill" side of each valve.
- **Outlet Tee to Valve Tubing:** Two sections of tubing are used to connect the fluid outlet tee to the "deliver" side of each valve.
- **Cylinder to Valve Tubing:** Two pieces of tubing connect the upper port on the cylinder barrel to the center section of the valve. (In between the cylinder barrel

and the valve is the safety rupture disk holder.) This tubing functions as both the inlet to and the outlet from the cylinder barrel.

- **Cylinder to Pressure Transducer Tubing:** One section of tubing connects each pump cylinder to a pressure transducer. The pressure transducer tubing connects to the lower fitting on the end of the cylinder barrel.

A. Valve Inlet Tubing

B. Valve Outlet Tubing

C. Cylinder–to–Valve Tubing (Two pieces per cylinder)

D. Cylinder–to–Pressure Transducer Tubing

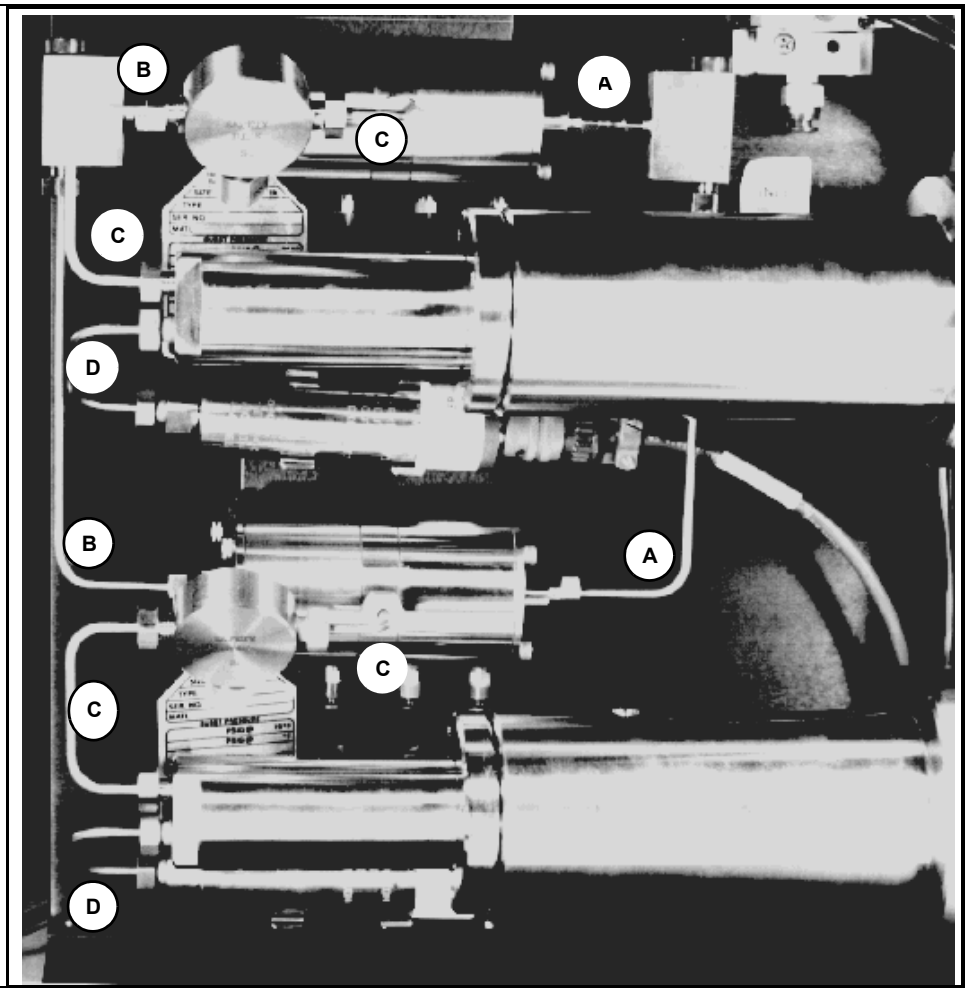

Figure 8-3 Plumbing Components for One Pair of Ambient Temperature C-5000 Cylinders

For high temperature systems, the tubing supplied with dual–cylinder high temperature stands are very similar to the tubing supplied with the ambient temperature systems.The major difference is the long length of tubing back to the pressure transducer, which is mounted outside the oven. Refer to Figure 8-4 for the identification of each of the following parts:

A. Valve inlet interconnect tubing
B. Valve outlet interconnect tubing
C. Cylinder–to–valve tubing
D. Cylinder–to–pressure transducer tubing

A. Valve Inlet Tubing

B. Valve Outlet Tubing

C. Cylinder–to–Valve Tubing (Two Pieces per cylinder)

D. Cylinder–to–Pressure Transducer Tubing

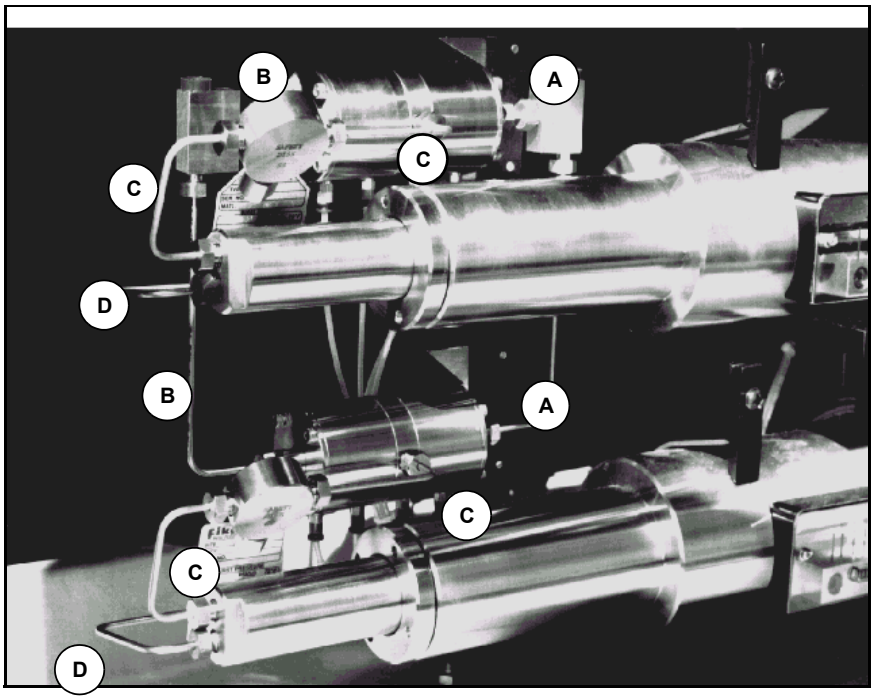

Figure 8-4 Tubing Components Supplied with the High Temperature System

IMPORTANT
Carefully check all fluid fittings for leaks. All pump systems are checked thoroughly and are fluid–tight at the time it is shipped. However, Quizix recommends that you carefully check all the fittings prior to operation and whenever the system is altered or moved. Most system leaks can be traced to fittings.

8.6 Safety Rupture Disks

Safety rupture disks are installed on each pump cylinder to prevent the system from exceeding a specified pressure. If the specified pressure is exceeded, the rupture disk bursts and fluid is expelled from the safety rupture disk fluid exit port.The fluid exit port is fitted with an Autoclave 1/8–inch Speedbite fitting so that tubing can be attached to vent fluid to a container.

IMPORTANT
Ensure that tubing is installed from the safety rupture disk port to an appropriate receptacle to prevent fluid from spraying into the atmosphere if the rupture disk is activated. This is particularly important if you are using flammable or highly corrosive fluids.

The safety rupture disk included in all Quizix pump systems is a ONE-TIME ONLY item that must be replaced if it is activated. It is not a pressure relief valve and cannot be tested. If you bring the system pressure up to the level at which the disk is designed to activate, it will rupture and must be replaced.

See Chapter 5, Section 5.3.4 for more information about the safety rupture disk. Also see Chapter 14 for instructions on replacing a safety rupture disk after it has been activated.

8.7 Hastelloy Option for Corrosive Fluids

The Quizix 5000 Series Pump System (including all fluid tubing, valves, safety rupture disk holders, and parts of the pump cylinder) is composed of either stainless steel (SS–316) or Hastelloy (C-276). If you pump fluids that are highly corrosive, such as brines or oils, then a Hastelloy option is available and recommended. The Hastelloy option is highly corrosion resistant and substantially extends the life of your pump system.

When the Hastelloy option is specified, all metal parts that come in contact with a fluid are made of Hastelloy C–276. These parts include the fluid-wetted parts in the C–5000 pump cylinder, the CV–310 valves, the safety rupture disk and its holder, the tubing for the fluid plumbing, and the fittings and tees. The pressure transducers, however, are only available in stainless steel. Non–metal parts that come into contact with a fluid include PEEK (in the valves), Teflon or UHMW seals, and o–rings of various materials.

8.8 High Temperature Option

The Quizix pump system is available in a high temperature version that allows the pump cylinders and valves to be heated up to 160°C. The following changes are made to the plumbing in high temperature systems:

- Tubing used for the air connections between the pilot solenoids and valves are constructed of Teflon instead of nylon.
- The fittings on the CV–310 valves, into which the air tubes are inserted, are Swage–type fittings instead of plastic quick–disconnect fittings. The Swage fittings have metal ferrules, which should be screwed tight when the air line is inserted.

When setting up a high temperature system, the following information regarding the valves, pilot solenoids and transducers should be considered.

8.8.1 Transducers

The standard pressure transducers operate at 70°C. They can be used at temperatures up to 80°C inside an oven without severely shortening their lifetime. However, for temperatures above 80°C, the pressure transducers must be mounted outside the oven. To facilitate their placement outside the oven, high temperature systems are shipped with a longer length of fluid tubing to connect the pressure transducer to the cylinder barrel.

8.8.2 Valves and Pilot Solenoids

The pilot solenoids for the valves cannot be placed in an oven. The pilot solenoids should be placed just outside the oven so that the air tubes connecting the pilot solenoids and the valves are as short as possible. See the Valve User's Manual for information about high temperature operation of the CV–310 valves. The high temperature valves can be heated to 160°C.

9 SYSTEM CABLES

The Quizix 5000 Series Pump System includes numerous cables that connect the components of the system. These cables are labeled so that connecting them should be self–explanatory. All of the cables necessary to operate the system are described in this chapter. Each cable is also described in the chapter(s) explaining the components to which it is connected.

9.1 Motor Cable

The motor cable, which is part of the motor assembly, connects the pump cylinder motor to the CMD-5000 Dual Controller Driver. One motor cable is provided for each pump cylinder in the system. This cable has a 9–pin, D–style connector at the CMD-5000 end and is permanently attached to the pump cylinder at the other end. The motor cable is a round, shielded cable.

Each motor cable must be plugged into the correct receptacle on the CMD-5000 Dual Controller Driver. The motor cable from Cylinder A should be plugged into the receptacle labeled “Cylinder A”; the motor cable from Cylinder B goes to the “Cylinder B” receptacle. If your system includes 3 or 4 pump cylinders, the motor cables from the third and fourth cylinders will connect in the same way to the second CMD-5000 in your system.

9.2 Sensor Cable

The sensor cable connects the pump cylinder sensor board to the CMD-5000 Dual Controller Driver. There is one sensor cable for each pump cylinder in the system. The sensor cable is a flat ribbon cable, and has a 15–pin, D–style connector at the controller end. Like the motor cable, each sensor cable must be connected to the correct receptacle on the controller. If you have three or four pump cylinders, their sensor cable will connect to the second CMD-5000.

At the pump cylinder end, there is a 14–pin ribbon connector with a key. The key is a ridge that fits into a corresponding slot on the receptacle. The connector fits only one way into the receptacle. You should not disconnect this cable at the pump cylinder end; it is more convenient to disconnect the controller end when re–configuring or moving the system.

Users with both a high temperature pump system and an ambient temperature pump system should note that the high temperature sensor cable differs from the low temperature sensor cable at the sensor board connection. Ambient temperature and high temperature sensor cables are not interchangeable.

9.3 Transducer and Valve Cable

The transducer and valve cable connects the CMD-5000 Dual Controller Driver to the pressure transducers and the pilot solenoids for the valves. There will be one transducer and valve cable for each CMD-5000 Dual Controller Driver in your system. This round, shielded cable has a 25–pin, D–style connector at the controller end.

The transducer portion of this cable has two branches. Each branch has a 6-pin circular connector that should be connected to one end of the pressure transducer. The branch labeled "Transducer A" should be connected to Transducer A on pump cylinder A; the branch labeled "Transducer B" should be connected to Transducer B on pump cylinder B.

The pilot solenoid portion of this cable has four branches, one for each pilot solenoid. (There are two pilot solenoids for each valve.) Each numbered branch has two wires, each with a 2-pin connector, that goes to a numbered pilot solenoid. If you reconfigure or move the pump system, this cable should be disconnected at the pump controller end and not at the pilot solenoid end.

Because the transducer and valve cable is designed for two pressure transducers and four pilot solenoids, if a user's pump system has an odd number of pump cylinders, there will be cable strands which are not used.

9.4 Data Link Cable

The Data Link Cable connects the CMD-5000 Dual Controller Driver with the serial expander/isolator. There will be one data link cable for each CMD-5000 in your pump system. The data link cable(s) should be plugged into the serial expander/isolator ports in sequence. For example, controller 1 connects with port A, controller 2 connects with port B, and so on. The data link cable has RJ-22 connectors (phone handset-type connectors) at both ends.

9.5 RS–232 Cable

The RS–232 cable connects the serial expander/isolator to the system computer. This cable has a 9–pin, D–style connector at both ends. The male end connects to the serial expander/isolator receptacle; the female end connects to one of the computer's serial ports. Most users connect the RS–232 cable to serial port 1. However, you can choose another serial port to connect the RS–232 cable to, if you specify this in the system communications. Use the Configure Communications window in the PumpWorks software.

The standard RS-232 cable can be extended with any standard straight–through (one–to–one) 9–pin cable.

9.6 AC Power Cables

The CMD-5000 Dual Controller Driver has a power cord with a 3–prong connector that must be connected to AC power, preferably by way of an Uninterruptable Power Supply. See Chapter 10 for more information. The power plug conforms to the standard outlet in the country to which the system is shipped. A standard IEC–320 appliance connector is used at the controller end of this cable

The computer and monitor to be used with your system should also be connected to AC power. Like the CMD-5000 Dual Controller Driver, it is best to use an Uninterruptable Power Supply if you wish to conduct long-term experiments, in which the interruption of fluid flow would be detrimental to the experiment's results.

9.7 User Interface Cable (Optional)

The User Interface Cable allows the 5000 Series Pump System to connect to various external devices, which the user may wish to add. Additional analog sensors, valves, digitally controlled devices and logic inputs, as well as power, are available on this 37-pin D-style connector. By connecting auxiliary valves, digital inputs, or analog inputs (such as additional temperature or pressure transducer readings) to the CMD-5000, the user will be able to access them from PumpWorks. The User Interface Connector also includes an emergency stop control signal for users who want to implement an emergency stop capability for their system.

Refer to Appendix B of the PumpWorks User's Manual for more information on the User Interface Cable, including the connector pin-outs. Refer to Chapter 9 of the PumpWorks User's Manual for more information on "Auxiliary Analog Input Signals" (Section 9.2), "Auxiliary Digital Input Signals" (Section 9.3), and "Auxiliary Valves" (Section 9.4) as they are viewed or controlled with PumpWorks.

If you have a recirculating pump system, a User Interface Cable will be included with your system and will be labeled "Recirculating Cable." It is used to establish communications between the controllers in recirculating systems.

9.8 Front Panel Cable (Optional)

The optional Front Panel Cable connects the CMD-5000 Dual Controller Driver with the Front Panel, which may be used instead of PumpWorks to control the pump system. The Front Panel is not currently available.

9.9 Cable Extensions

Quizix supplies the correct cable lengths for stand-mounted ambient temperature systems and for high temperature systems where the pump cylinders and valves are placed in an oven and the other pump system components are outside the oven. If a user converts an ambient temperature system to a high temperature system, or reconfigures a pump system in any way that requires longer cables, replacement cables can be ordered in longer lengths.

The motor cable can be extended, if necessary. Although Quizix recommends that the motor cable be kept as short as possible, Quizix manufactures a 2-meter motor cable extension.

There are no extension cables available for the sensor cable, transducer and valve cable, or data link cable, but the user can order new cables in a longer length, if necessary. The RS-232 cable can easily be extended with a standard straight-through (one-to-one) 9-pin cable.

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10 SYSTEM POWER

This chapter describes the power requirements for the 5000 Series Pump System. Included are the following:

- Basic Power Requirements, Section 10.1
- Using Uninterruptable Power Supplies, Section 10.2
- Changing the Voltage Setting, Section 10.3
- Replacing a Fuse, Section 10.4

10.1 Basic Power Requirements

The Quizix 5000 Series Pump System has two components that must be connected to a power source: the CMD-5000 Dual Controller Driver and the computer. All Quizix Pump Systems are set to the voltage of the country to which they are being shipped: 110–120 or 215–240 volts. The voltage setting of the CMD-5000 Dual Controller Driver can be changed if necessary.

All 5000 Series Pump Systems are shipped with power cords compatible with the voltage and type of outlet used in the country to which they are shipped. If a computer is ordered with a pump, the computer is also configured to the power requirements of the country to which it is shipped.

Users conducting long–term experiments, in which the interruption of fluid flow would be detrimental to the experimental results, should use an Uninterruptable Power Supply (UPS) with their system.

10.2 Using Uninterruptable Power Supplies

The 5000 Series Pump System can operate for extended periods of time (that is, many months) without needing to be stopped. This capability is perfect for running long–term experiments such as steady–state rock property measurements. In order to operate, however, the pump system must have a source of AC power available at all times. Electronic equipment, such as computers and the CMD-5000 Dual Controller Driver, can be affected by brief power interruptions and power line surges or spikes. These power fluctuations can be caused by the power company or lightning strikes and can cause the pump to stop operating. It is, therefore, strongly recommended that users interested in obtaining data over extended periods of time use an Uninterruptable Power Supply (UPS) with their equipment.

Quizix recommends a UPS that provides continuous on–line filtering and good AC line noise rejection, as well as power backup capabilities. Also, it is recommend that the time required for the unit to switch to back–up power be less than a few milliseconds.

The proper size for a UPS must be determined, based on your specific pump system and the type of power losses that are normally experienced. The first item that must be determined is the pump system's power consumption. This can be determined using Table 10-1.

To keep the Quizix pump system operating, only the CMD-5000 Dual Controller Driver needs to be connected to the UPS supply. The computer can be turned off without affecting the operation of the pump system. However, if the computer is used to log data or perform timed operations, such as ramping of rates or pressures with the AutoOp feature, then the computer must also be connected to the UPS. The monitor does not have to be connected to the UPS, unless you want to view data or manually change parameters during a power outage.

Although many devices provide wattage (W) ratings, most UPS systems are rated in volt–amps (VA). Both ratings are listed for Quizix components in Table 10-1.

Table 10-1 UPS Ratings

Component	Wattage	Volt–Amp
CMD-5000 Dual Controller Driver		
(2 pumps, stopped)	30	40
(2 pumps, fully loaded)	80	120
Typical Windows computer	60–400	80–500
Typical Windows monitor	50–200	70–250

The next item that should be considered is the length of time a power outage is likely to last. Enough battery capacity must be available at the load required to last for the length of the power outage. Most UPS systems list how long their battery can supply full and half load power. This information can be used to determine the expected run–time with the load from the above calculation. Extra battery packs can be obtained for most UPS systems.

In case of an unusually long power outage, considerable power can be saved by turning off the monitor or both the monitor and the computer. Further power savings can be obtained by stopping the motors or running them at slower rates. Turning off equipment, of course, requires that the user be present.

If power to the motor driver is lost (motors de–energized), the pump cylinders will back–drive and lose volume information if the cylinder pressure is above 2000 psi. For pressures below 2000 psi, the residual holding torque of the motors, combined with the friction of the mechanics, can hold the piston in place. For pressures above 2000 psi, the pressure forces on the piston are high enough to cause the ball screw to rotate and push the piston backward until the cylinder pressure drops below 2000 psi.

10.3 Changing the Voltage Setting

The Quizix 5000 Series Pump System can operate at 110–120 or 215–240 volts. If you must change the voltage setting in a system with 5000 Series pump cylinders, you can do so by changing the fuses and settings on the CMD-5000 Dual Controller Driver. Follow the instructions below.

1. Unplug the CMD-5000 and the computer. On the controller, note the modular power connector assembly, which includes a receptacle for the power cord, a fuseholder, and a

voltage selector in one unit. Note that there is a very small white indicator displaying the voltage for which the controller is currently set.

2. Pop out the fuseholder located directly next to the power cord receptacle. Use a small screwdriver in the slot (hole) to loosen the fuseholder.
3. Change the fuse to the appropriate amperage rating for the voltage you want to use. The following shows the appropriate fuse ratings:
   - For 120 Volts: 1.5 am fuse
   - For 220-240 Volts: 0.75 amp fuse:
4. Using a small set of pliers, pull out the white voltage selector, (a tiny white PCB) from the space next to the fuseholder.

   The voltage selector is roughly the shape of a square with a plastic voltage indicator (a white plastic piece) on it. Each side of the voltage selector contains a voltage number and an arrow. The plastic voltage indicator should be nested in the notch on the **opposite** edge of the voltage you want to select. It should be oriented in the same direction as the arrow next to the selected voltage.
5. To change the selected voltage, slide the plastic indicator around the square, making sure it settles into the correct notch on the outside edge and the appropriate space inside the square.
6. Press the voltage selector back into its space until it snaps into place. Insert it right side up and in the direction of the arrow next to the selected voltage. The voltage indicator (the white plastic piece) is on the outside so that it shows when the fuseholder is replaced.
7. Replace the fuseholder in its space. Ensure that the white plastic indicator is in the correct setting for the voltage you want.
8. To change the voltage setting for the computer you are using with your pump system, consult the operator's manual for your computer.

   Many computers have a switch for changing the voltage setting. Many monitors have an autoswitch power supply (set to 100–250 volts) and do not need to be changed.

10.4 Replacing a Fuse

If a fuse blows in the CMD-5000 Dual Controller Driver, replace it by following Steps 1, 2 and 3 in Section 10.3. Then replace the fuseholder (Step 7).

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11 MAINTENANCE

This chapter describes preventive and corrective maintenance for the Quizix 5000 Series Pump system. This chapter includes:

- Special Tools and Spare Parts Kit, Section 11.1
- Changing the Cylinder Barrel Seals, Section 11.2
- Maintaining the Pump Cylinder, Section 11.3
- Cooling Fan Maintenance, Section 11.4
- Replacing the Safety Rupture Disk, Section 11.5
- Calibrating the Pressure Transducers, Section 11.6
- Valve Maintenance, Section 11.7

NOTE: For the purposes of this manual, the term "regular use" is defined as using the pump system 2 to 3 days per week, every week, at pressures above 35% of the rated pump pressure or at rates above 35% of the maximum pumping rate. If you are operating at lower pressures, very low rates, or infrequently, then the stated service intervals can be increased. Some conditions may require servicing the pump system more often.

CAUTION
As a general safety precaution, always verify that there is no pressure in the pump before performing any service procedures. To accomplish this, open the valve (typically the fill valve), which vents the system to atmosphere.

11.1 Special Tools and Spare Parts Kit

Each Quizix pump system is shipped with a set of special tools and a spare parts kit that you should use to service your system. Stand–mounted systems have a tool box mounted on the stand where these tools and spare parts are located. A description of the special tools is described in Table 11-1. The spare parts kit is described in Table 11-2.

Table 11-1 Special Tool Kit		
Item No.	**Tool**	**Description**
1	1/2–inch angled open–end wrench	The 1/2 inch angled open-end wrench is used to tighten the Speedbite® fittings and is especially useful for tightening the two ports on the cylinder barrel.
2	22 mm open–end wrench	The 22 mm open-end wrench fits the flat area of the cylinder barrel. It is used to hold the barrel in place while tightening the fluid fittings, or while tightening the cylinder barrel retaining ring.
3	Adjustable face spanner wrench	The adjustable face spanner wrench is used to loosen and tighten the cylinder barrel retaining ring. It is also used to remove and install the seal retaining nut or wash ring assembly, if your system has one.
4	Seal extraction rod	The seal extraction rod is a smooth metal rod with the same outside diameter as the piston. It is used to extract a seal without damaging the cylinder.
5	Seal guide ring	This ring guides the seal insertion plunger into the cylinder during seal replacement.
6	Seal insertion plunger	This is a 3–step cylindrical rod used to push a seal out of the seal guide ring and into the cylinder barrel.
7	27 mm socket on extension tube	This socket is inserted into the cylinder housing to engage the piston nut during piston removal or replacement.
8	Speedbite® plugs and nuts (2 each)	These parts are used to close off the fluid ports during seal extraction.

Table 11-2 Spare Parts Kit	
Item No.	**Spare Part**
1	Seals Depending on the type of pump system that is ordered, the seals included are one of the following: • Cup–type ambient temperature seals made of ultra–high molecular weight polyethylene (white UHMW P–E) • T–type high temperature seals made of Aflas® (black) with accompanying Teflon® back–up ring.
2	CMD-5000 Dual Controller Driver fuse
3	Safety rupture disk. This is used in the safety rupture disk assembly.

11.2 Changing the Cylinder Barrel Seals

This section describes how to change the cylinder barrel seals and the piston. It includes the following:

- Removing the Cylinder Barrel, Section 11.2.1
- Changing the Seals, Section 11.2.2
- Inspecting, Removing, Cleaning, and Re–Installing a Piston, Section 11.2.3
- Replacing the Cylinder Barrel, Section 11.2.4

Recommended frequency for this maintenance section:

- For ambient temperature systems—every 1 year of regular use, or as required.
- For high temperature systems—every 6 months of regular use, or as required.

11.2.1 Removing the Cylinder Barrel

NOTE: This procedure is the same for both ambient and high temperature systems.

IMPORTANT
Excessive side loads on the piston during cylinder barrel installation or removal may break the piston.

1. Ensure that the piston is fully retracted before removing or installing the cylinder barrel.This minimizes the side forces on the piston during cylinder barrel removal and

installation. Operate the pump so that the piston is in its Max Retract position before proceeding.

2. Remove the Speedbite fittings from the end of the cylinder barrel and tip the cylinder downward to drain its fluid.
3. Use the adjustable face spanner wrench to remove the cylinder barrel retaining ring nut. Refer to Chapter 7, Chapter 7-2 if needed.
4. Grasp the cylinder barrel by hand and pull it **straight out** from the cylinder housing. Be sure to pull it straight out and away from the cylinder housing. Never put any sideways force on the cylinder barrel because this may break the piston.

   If an active wash assembly is used, a firm pull and some twisting back and forth may be necessary to get the cylinder barrel to move initially. Once the cylinder barrel is released from the body of the cylinder, continue to pull **straight back** until the seal and seal backup ring are released from the piston.

   For best results, remember to keep cylinder barrels, seal back–up rings and pistons together and reinsert them into the cylinder they were removed from. For example, the back–up ring and piston from cylinder 1A should be re–installed into cylinder 1A.

NOTE: Usually some fluid remains in the pump cylinder and spills out when the piston is free from the seal. Be prepared to catch or wipe up this excess fluid. When the cylinder barrel is completely detached, it can then be cleaned and inspected.

11.2.2 Changing the Seals

Seal life depends on the type of seal used and the operating conditions of the pump (pressure, flow rate, and type of fluid that is pumped). The design of all Quizix pump cylinders makes changing seals a simple procedure. This section instructs the user how to change seals. Included are the following:

- Cup-Type and T-Type Seals, Section 11.2.2.1
- Seal Removal Procedure for All Seals, Section 11.1.2.2
- Seal Insertion Procedure for Cup–Type Seals, Section 11.2.2.3
- Seal Insertion Procedure for T–Type Seals, Section 11.2.2.4

11.2.2.1 Cup-Type and T-Type Seals

The cup–type seal used in Quizix pumps is shown in Figure 11-1. It is asymmetrical, with one side flat and one side having an open area around its circumference, with a metal spring inside this opening. A cross–section of this type of seal resembles a cup, or, the letter U.

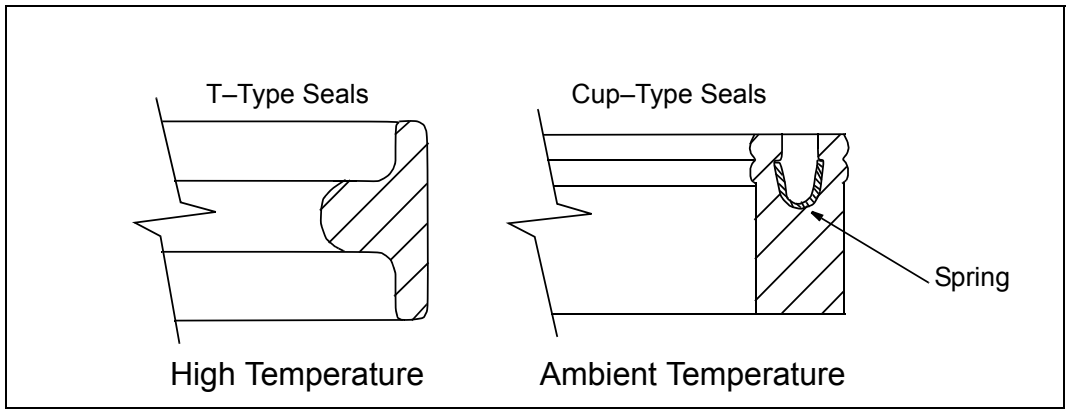

Figure 11-1 T-Type and Cup-Type Seals

Cup–type seals are made from ultra–high molecular weight polyethylene (UHMW–PE) and used in ambient temperature applications and are normally white. Cup–type UHMW– PE seals have the longest life, one year minimum for normal service and two–plus years are possible. Pressure, flow rate, and fluid type do not significantly affect the life of these seals.

High temperature applications normally use a T–type seal made of Aflas. Some high temperature applications, however, have used carbon–loaded Teflon cup–type seals. The high temperature seals have a shorter lifespan, which is strongly dependent on pressure and is related to flow rate and the type of fluid that is pumped. A normal effective life for these seals is six months of continuous use.

11.1.2.2 Seal Removal Procedure for All Seals

IMPORTANT
To get maximum performance from the seals, great care must be used when handling and inserting them. The high temperature Teflon® seals are especially sensitive to damage by scratches that are not easily visible to the unaided eye. The seals can be easily scratched by any sharp object, including fingernails. The cylinder seal cavity can also be scratched easily. Therefore, do not use any sharp or hard objects to remove a seal or to clean a pump cylinder.

The assembly tools and components for ambient temperature UHMW P–E and high temperature Teflon® seals are shown in Figure 11-2.

1. When the cylinder barrel is removed from the cylinder housing, remove the seal retaining nut using the face spanner wrench, while holding the cylinder barrel with the 22 mm wrench.
2. If desired, remove the seal back–up ring.
3. Plug both cylinder barrel ports with Speedbite® plugs.
4. Fill the cylinder barrel approximately 3/4 full with fluid (water is best) and firmly press the seal extraction rod through the seal and into the cylinder barrel. (Refer to Table 11-1 for a description of the seal extraction rod tool.) This procedure creates pressure in the

cylinder barrel. This causes the seal to pop out of the seal cavity and remain on the seal extraction rod. If the seal sticks and does not pop out when the rod is inserted, press the rod in again to create pressure in the cylinder. Then, pull back on the rod to extract the seal. Remember, if you plan to re–use the seal, handle it very carefully once it is removed.

5. Inspect both the seal and the cylinder barrel for scratches, the presence of foreign objects, and sharp edges. Using a magnifying glass, examine the outer surface of the seal for scratches along the piston axis.
6. Examine the inside lips of the seal for scratches or deformations. Pay close attention to the area around the joint in the tensioning spring. This area should be smooth and not show deformities due to the spring joint.
7. Examine the cylinder barrel cavity for scratches. The cavity surface should be smooth, clean, and free of contaminants.

NOTE: A seal or a cylinder barrel with scratches will result in leaks when operated. Ensure that the seal and cylinder seal area are very clean. Lint or dirt on a seal can cause seal leakage. If possible, the seal should be cleaned in an ultrasonic cleaner or with a Q–tip® just before insertion.

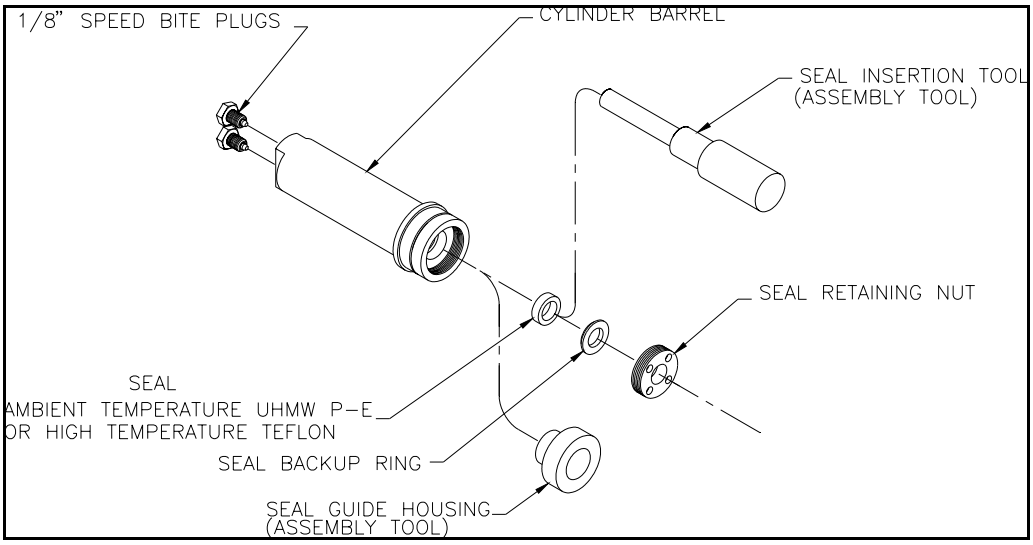

Figure 11-2 Seal Insertion Tools and Components

If both the seal and cylinder are in good condition, proceed with the seal insertion. If you plan to replace the old seal, inspect and clean a new seal prior to installation.

11.2.2.3 Seal Insertion Procedure for Cup–Type Seals

1. Coat the seal on both the inside and outside surfaces with a light coat of lubricating compound. Petroleum jelly or vacuum grease works well for this purpose. Almost any type of lubricating compound will work -- even water, if no oils are available.
2. Apply a light coat of lubrication to the inside surface of the seal insertion guide ring, and the seal insertion plunger. Apply lubricating compound to the cylinder seal cavity entrance. A small amount of lubricant is sufficient.
3. After all surfaces that touch the seal are coated with lubricating compound, carefully slide the seal onto the seal insertion plunger. The seal spring should face towards the

tapered end of the plunger. The seal should slide on smoothly and easily. Push the seal on until it contacts the plunger shoulder.

4. Slide the seal guide ring into the cylinder barrel so that it is pressed against the seal cavity. When properly seated, only a very small gap should exist between the seal guide ring and the end of the cylinder barrel.
5. Use the seal insertion plunger to press the seal into the cavity. Press the plunger down as far as possible until it contacts the seal guide ring. At the last 0.5 cm of insertion, a small amount of pressure is felt as the seal compresses to slide into the cavity.
6. When the seal is fully inserted, retract the seal insertion plunger with a twisting motion, leaving the seal fully inserted in the seal cavity of the cylinder barrel.
7. Carefully insert the seal backup ring with its shoulder (smaller diameter) towards the seal.
8. Coat the seal retaining nut threads with an anti–seize compound. Screw the seal retaining nut into the cylinder barrel to hold the seal back–up ring and seal in place. Hand tighten the nut, using the 22 mm wrench to hold the cylinder barrel and the face spanner wrench on the seal retaining nut.

11.2.2.4 Seal Insertion Procedure for T–Type Seals

There are two major differences between high temperature Aflas® seals shown in Figure 11-3, and the cup–type seals discussed in the previous sections. The differences are the following:

- There are five components in the Aflas® seal assembly.
- There are no assembly tools used in the insertion of this seal assembly. All parts are inserted by hand.

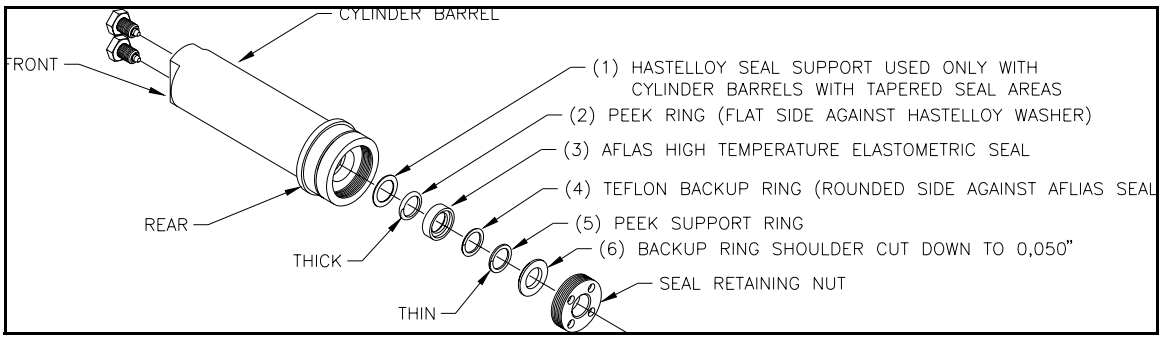
CYLINDER BARREL
FRONT
(1) HASTELLOY SEAL SUPPORT USED ONLY WITH CYLINDER BARRELS WITH TAPERED SEAL AREAS
(2) PEEK RING (FLAT SIDE AGAINST HASTELLOY WASHER)
(3) AFLAS HIGH TEMPERATURE ELASTOMETRIC SEAL
(4) TEFLON BACKUP RING (ROUNDED SIDE AGAINST AFLIAS SEAL
(5) PEEK SUPPORT RING
(6) BACKUP RING SHOULDER CUT DOWN TO 0,050"
SEAL RETAINING NUT
REAR
THICK
THIN

Figure 11-3 Order and Orientation of Aflas Seal Assembly Components and Outer Backup Ring.

In the following procedural steps, the numbers in parentheses correspond to the numbers next to the component labels shown in Figure 11-3.

1. On cylinder barrels with tapered seal areas, place the Hastelloy seal support (1) into the cylinder barrel. On cylinder barrels with a *step*, rather than a taper after the seal in the seal area, Hastelloy seal supports are not used. If the seal support does not sit flat (perpendicular to the center axis of the barrel), the seal insertion plunger can be used to lightly tap it into place.

2. Place the PEEK ring (2) into the barrel with its flat side against the Hastelloy seal support and its rounded side toward the front of the cylinder.
3. Push the Aflas® seal (3) into the cylinder barrel as far as possible until it is up against the PEEK backup ring. The Aflas high temperature seal is elastomeric so it can be slightly compressed by hand.
4. Place the Teflon® rear backup ring (4) into the barrel, with its rounded side against the Aflas® seal.
5. Place the flat PEEK rear support ring (5) against the Teflon® bottom backup ring.
6. Place the large PEEK backup ring (6) against the rear support ring with the shoulder (smaller diameter) towards the seal, against the Teflon® backup ring. This last backup ring has a smaller shoulder than the standard, ambient temperature seal backup ring. If you have both types of backup rings on your work table, do not confuse them.
7. Gently force the seal insertion plunger through this set of seals and rings to align them.
8. Coat the seal retaining nut threads with an anti–seize compound, then screw it into the cylinder barrel to hold the seal back–up ring and seal in place. Tighten this nut using the face spanner wrench. Use the 22 mm wrench to hold the cylinder barrel.

11.2.3 Inspecting, Removing, Cleaning, and Re–Installing a Piston

WARNING
THE PISTONS ARE MADE OF SILICON CARBIDE AND ARE VIRTUALLY UNSCRATCHABLE, BUT THEY ARE SLIGHTLY BRITTLE AND CAN BREAK. KEEP SIDE FORCES TO A MINIMUM AND DO NOT DROP THEM.

11.2.3.1 Inspecting and Cleaning a Piston

A piston that is installed in a pump can be inspected by doing the following: (It is assumed that the cylinder barrel has already been removed as described in Section 11.2.1)

1. Operate the pump to move the piston to the Max Extend position.
2. Inspect the piston carefully, looking for deposits or obvious damage, then wipe it clean with a clean, lint–free cloth.
3. If deposits are found, clean the piston with a solvent and a nylon (Scotchbrite®) type scrub pad.
4. If some deposits cannot be removed while the piston is installed, or if you want to soak the piston in a solvent, use the 27 mm socket wrench with an extension to remove the piston.

Inspect a piston that is removed from the cylinder housing by doing the following:

5. Inspect the piston carefully, looking for deposits or obvious damage, and wipe it clean with a clean, lint–free cloth.
6. If deposits are found, clean the piston with a solvent and a nylon Scotchbrite®–type scrub pad, or soak it in a cleaning solvent until deposits are removed.

7. If deposits are not found, re–install the piston as described in the next section.

11.2.3.2 Re–installing the Piston

1. Wipe the piston clean with a clean, lint–free cloth. Coat the piston's threads with an anti–seize compound, then use the 27 mm socket wrench with an extension to re–install it into the pump housing.
2. To prepare to re–install the cylinder barrel into the cylinder housing, coat the tip of the piston with a lubricating compound such as petroleum jelly or vacuum grease (or water, if oils are not permitted). A small amount is sufficient to cut seal insertion friction.
3. Operate the pump to move the piston to its Max Retract position to protect the piston in preparation for re–installing the cylinder barrel.

11.2.4 Replacing the Cylinder Barrel

1. Ensure that the pump is at its Max Retract position.
2. If your pump system has an active wash ring, inspect the two wash ring external o–rings for signs of nicks or deterioration. If necessary, replace them. Using a lubricant like vacuum grease, coat the outside o–rings completely around their circumference. This allows the o–rings to be inserted without binding.
3. Holding the cylinder barrel assembly in one hand, carefully insert it straight onto the piston, then into the cylinder housing. A firm pressure and some slight twisting action may be necessary to get the cylinder barrel assembly fully seated in the cylinder housing.
4. Screw on and tighten the cylinder retaining ring nut with the face spanner wrench.
5. Test the pump for proper operation and seal performance (no leaks).

11.3 Maintaining the Pump Cylinder

This section describes cylinder maintenance. It includes the following:

- Replacing the Cam Rollers, Section 11.3.1
- Re–Greasing the Ball Screw, Section 11.3.2
- Re–Greasing the Harmonic Drive Bearing, Section 11.3.3

11.3.1 Replacing the Cam Rollers

Recommended Frequency:

- For ambient temperature systems—every 2 years of regular use, or as required.
- For high temperature systems—every year of regular use, or as required.

Both the left and right side covers on the ambient temperature pump cylinder have vertical lines that are numbered 0 through 10. When the pump is operating, the relative position of the piston can be monitored by watching the cam roller, which is attached to the ball nut, move from one line to the next.

There is a cam roller on each side of the pump cylinder. Different cam rollers are used for high temperature and ambient temperature systems. These components, while simple, perform an important job in the pump cylinder. But their internal lubrication can dry out over time, especially on the high temperature pump systems. This procedure explains how to confirm the cam rollers are working properly, are lubricated correctly and, if necessary, how to replace them. Refer to Figure 11-4 and Figure 11-5. The cam roller and stand–off shown in Figure 11-5 is shown magnified and with the roller slightly unscrewed for clarity.

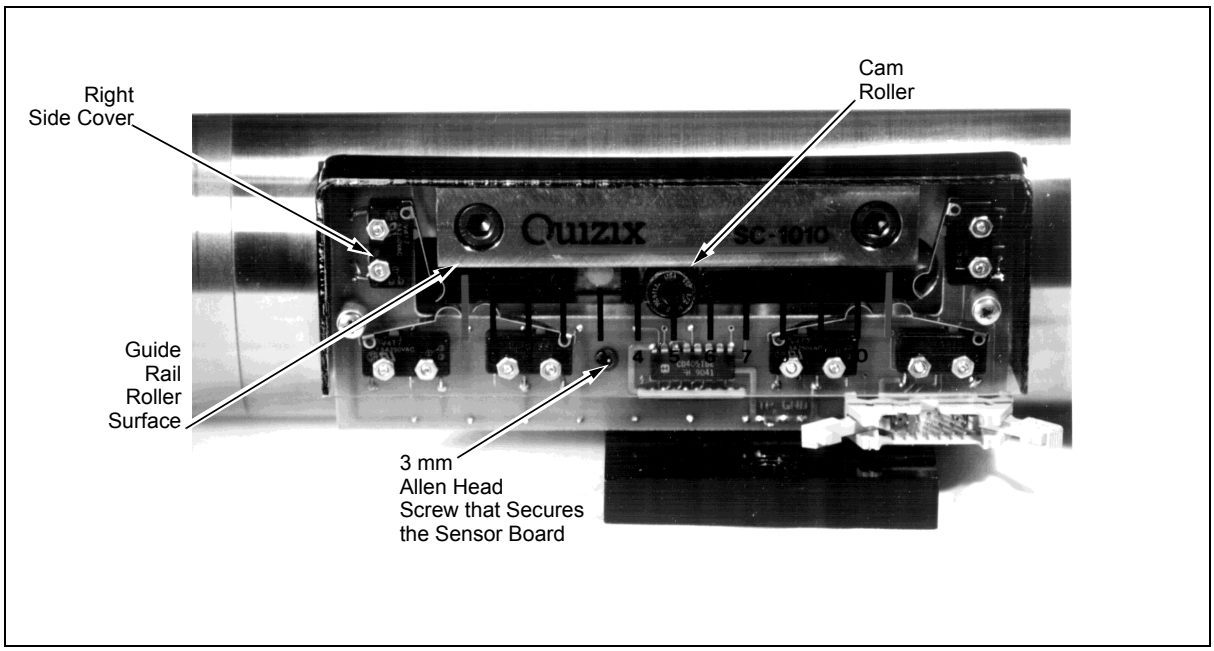

Figure 11-4 Right–Side Cam Roller

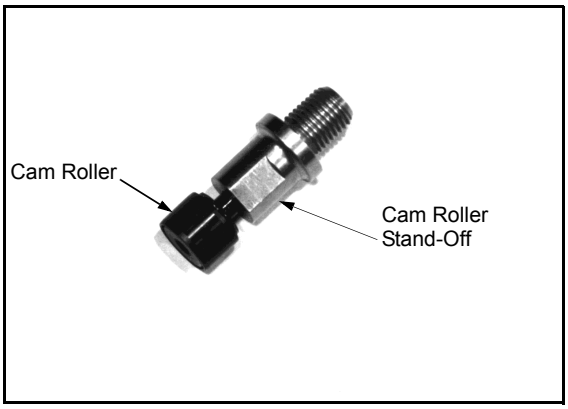

Figure 11-5 Cam Roller and Stand Off

1. Remove the right side cover (two Phillips head screws).
2. Remove the sensor board and set it aside (one 3 mm socket head cap screw). This step is recommended, but not mandatory.
3. To determine if the cam roller needs replacing, check the following:

a. Grasp the cam roller with two fingers and make sure it feels smooth and non–binding when it is rotated.

b. If the steel guide rails (see Figure 11-4) on which the rollers roll, have any marks on them other than a straight "wear path" parallel to the sides of the rails, the rollers should be replaced.

c. If a high temperature system has more than two years of regular use at high temperatures, the rollers should be replaced.

4. Use a 10 mm open end wrench and slide it over the flats of the cam roller stand–off, which is screwed into a ball nut bracket.

5. While holding the stand–off in place, place a 1/8–inch Allen wrench into the center of the cam roller and unscrew the cam roller from the stand–off.

6. Replace the faulty cam rollers with the proper type (either high or ambient temperature) by holding the stand–off in place with a 10 mm open end wrench, and using a 1/8–inch Allen wrench to screw the cam roller into the stand–off. Always replace them in pairs, never as single rollers.

NOTE: The recommended cam roller to use for ambient temperature systems is the McGill Model CCF 1/2 N SB. For high temperature systems, the recommended roller is the McGill CCF 1/2 NB–W1K.

Repeat Steps 1 through 6 for the left side cam roller, disregarding references to the sensor board.

11.3.2 Re–Greasing the Ball Screw

Recommended Frequency:

- For ambient temperature systems—every 2 years of regular use, or as required.
- For high temperature systems—every year of regular use, or as required.

The Quizix pump cylinder has a side cover on each side of the pump cylinder. The ambient temperature side cover contains a clear, acrylic panel on the outside, through which the sensor board (right side) or the ball screw (left side) can be viewed. The high temperature covers are black anodized aluminum with a slot cut into them for viewing. Refer to Figure 11-6 for a view of the pump cylinder clarifying the left and right sides and Figure 11-7 for a view of the pump cylinder cam roller and ball screw.

Figure 11-6 Pump Cylinder Overhead View

Figure 11-7 Pump Cylinder Side View

To grease the ball screw, use the following procedure.

1. Remove the left side cover (the side opposite the sensor board).
2. Extend the pump to the Max Extend position.
3. Use a small flashlight to look into the long cut–out opening in the side of the pump cylinder where the ball screw is clearly visible.
4. Visually inspect the ball screw and ensure that there is at least a small amount of lubricant on it, that there is no visible rust on any surface, and that any visible lubricant is not dried out or granular. If any of these irregularities are evident, the ball screw may need major service or replacement, and Quizix should be contacted.

5. Use a small brush with short, stiff bristles, or another small applicator, and dip it into a container of grease. The type of grease to use is listed below:
   - For ambient temperature systems, use HD Systems HC–1 grease, or an equivalent.
   - For high temperature systems, use DuPont Krytox GPL 216 grease, or an equivalent.
6. Apply the grease along the entire visible section of the ball screw.

WARNING
ANY SMALL APPLICTOR MAY BE USED TO APPLY THE GREASE. A STIFF, SHORT–BRISTLED BRUSH IS ADEQUATE, BUT USE CAUTION TO ENSURE THAT ABSOLUTELY NO BRISTLES ARE LEFT ON THE BALL SCREW OR IN THE GREASE.

7. Operate the pump at low speed until the ball screw retracts one–half turn, so that the greased side has rotated away from you (0.25 inches of travel for the cam rollers), and again apply the grease along the entire visible length of the screw.
8. Replace the left side cover.

The system is now ready for normal use.

11.3.3 Re–Greasing the Harmonic Drive Bearing

Recommended Frequency: For all systems—every 2 years of regular use.

1. Power down the complete pump system, especially the CMD-5000 Dual Controller Driver, and disconnect the 9–pin connector on the motor cable from the CMD-5000. See Figure 11-8 for the three major assemblies discussed in this procedure.

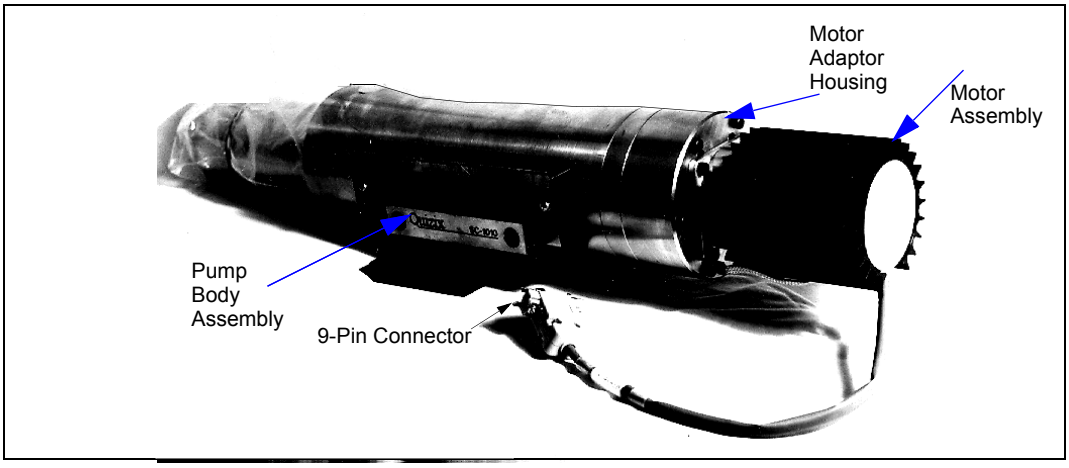

Figure 11-8 Pump Motor Assembly

2. Use a 3 mm right angle Allen wrench to break loose the six M4 socket head cap screws (SHCS) securing the motor adapter housing to the pump body. See Figure 11-9 for the

location of the mounting screws that secure the motor adapter to the pump body housing. A ball–end Allen driver can then be used to remove the screws.

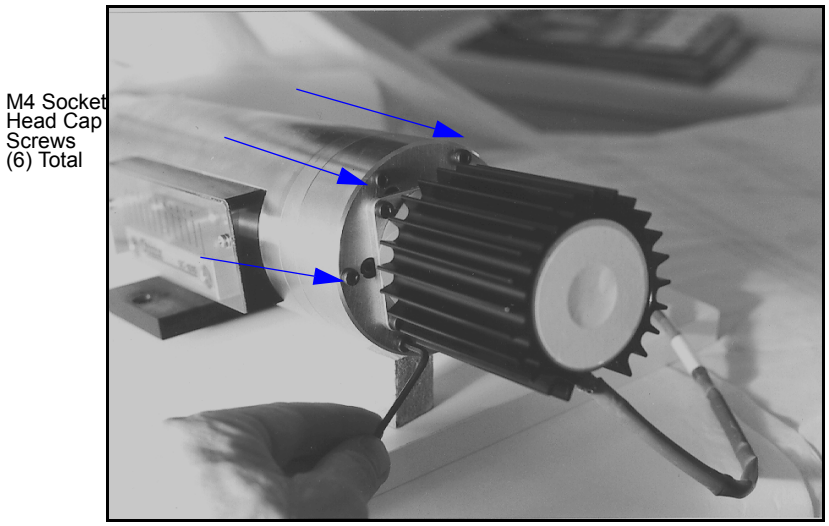

Figure 11-9 M4 Socket Head Screw Locations

3. Set the pump body assembly aside.
4. Viewing the open end of the motor adapter housing, remove the snap–ring from the motor shaft. See Figure 11-10.

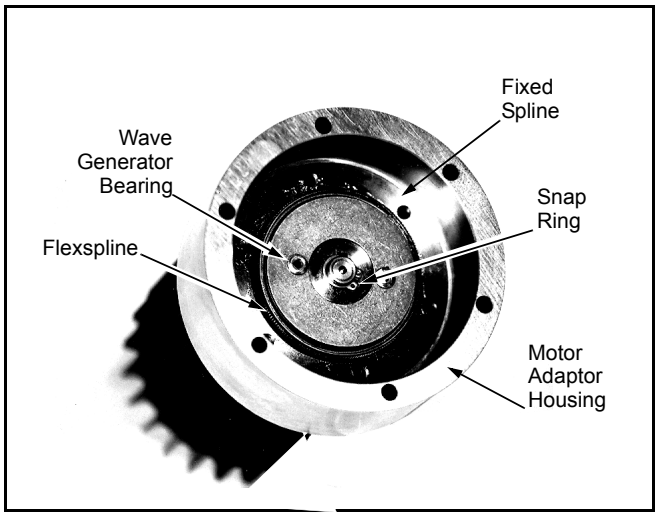

Figure 11-10 Open End of the Motor Housing

5. Holding the motor assembly firmly in one hand with the open end of the motor adapter housing facing down, sharply rap the flat surface of the motor adapter housing on a thin piece of cardboard placed on a solid surface. See Figure 11-11. Only one or two sharp raps should be needed to dislodge the wave generator bearing, the flexspline, the motor shaft key, and the Lexan® washer. Any clean, slightly cushioning surface will work for this step, but wood is not recommended because small wood chips could get lodged in the ball bearings.

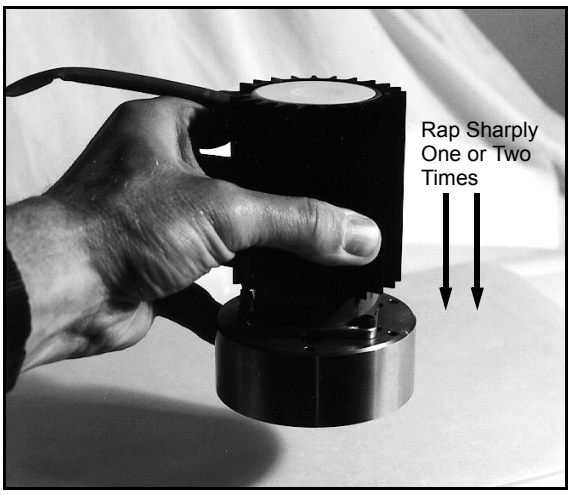

Figure 11-11 Dislodging the Wave Generator Bearing

NOTE: The flexspline is the slightly flexible spline that fits on the outside of the wave generator bearing. It has external teeth.

6. Verify that all four components: the wave generator bearing, the flexspline, the motor shaft key, and the Lexan® washer, dislodge from the motor adapter housing. Set them aside.

NOTE: The flexspline may not easily separate from the wave generator bearing. If these parts do separate, gently slide the flexspline back onto the wave generator bearing. If they do not separate, proceed with this procedure.

7. The fixed spline (refer to Figure 11-10) will still be attached to the motor adapter housing. Visually inspect the fixed spline, making sure that there are no obvious signs of broken teeth, unusual wear patterns, or foreign particles in the grease.
8. Using a clean, lint–free cloth, wipe off as much grease as possible from the internal teeth on the fixed spline, then apply HD Systems HC–1 grease (or equivalent) to all of the internal teeth.
9. Repeat Steps 7 and 8 for the dynamic spline, which is clearly visible and accessible on the pump body assembly.
10. Perform the same visual inspection (described in Step 7) to the wave generator bearing, looking closely at its open side where its bearings are exposed. Manually spin the bearing assembly, making sure that it rotates smoothly.
11. Using a clean, lint–free cloth, wipe off as much grease as possible from the exposed ball bearings. If desired, the entire bearing assembly may be soaked in an appropriate solvent to remove the grease.
12. Apply HC–1 grease (or equivalent) to the entire area of the wave generator bearing where the ball bearings are exposed.
13. If the flexspline has been separated from the wave generator bearing, carefully slide it back onto the outer bearing race.

14. Set the motor assembly with the motor adapter housing facing up, as shown in Figure 11-10.
15. Slide the Lexan washer onto the motor shaft.
16. Replace the key in the motor shaft, using a small amount of grease to make it stick in the keyway.

Figure 11-12 View of Keyway

NOTE: The key is slightly wider than it is high. Place it in the shaft keyway with its wide side down.

17. Grasp the wave generator bearing in one hand and, looking straight down at the motor shaft and its key, carefully slide the bearing and spline over the center shaft. The orientation of the bearing is very important. As shown in Figure 11-10, the two rivets in the bearing should be facing out and the uncovered ball bearings should be in against the motor.
18. If this assembly becomes stuck on the motor shaft, or if it does not slide completely on, repeat Step 5 in this procedure to remove the bearing, then try again.
19. Use a standard paper clip or equivalent probe to confirm that the key is still in place on the motor shaft by probing in the keyway for the key.
20. The flexspline may not slide completely down at first. If this occurs, gently slide it down into the fixed spline until it feels like it has “bottomed–out”. When properly in place, the top edge of the flexspline should be slightly below the top surface of the wave generator bearing.
21. The snap–ring that secures the wave generator bearing to the motor shaft is not flat. When seen from the side, its shape has a slight bend or curve to it as shown in Figure 11-13. Place the snap–ring on a work surface with the concave side down and pick it up with the snap–ring tool. Be careful not to expand it more than necessary.

Figure 11-13 Concave View of Snap–Ring

22. Open the snap–ring just enough to slide it onto the end of the motor shaft and into the shaft's slot.
23. Use a #1 standard screwdriver to press down on the top, convex surface of the snap–ring until it fully snaps into its slot. See Figure 11-13.

WARNING
IT IS EXTREMELY IMPORTANT THAT THE SNAP–RING IS PROPERLY AND COMPLETELY IN PLACE ON THE MOTOR SHAFT. WHEN PLACING THE SNAP–RING ON THE SHAFT, DO NOT OPEN IT ANY MORE THAN NECESSARY. IF THE SNAP–RING IS NOT PROPERLY IN PLACE, THE WAVE GENERATOR BEARING MAY COME OFF OF THE MOTOR SHAFT AND SERIOUS DAMAGE TO THE QUIZIX SYSTEM WILL RESULT.

24. Use the six M4x40 SHCS to secure the motor assembly and motor adapter housing to the pump body, making sure that the cable is down, towards the base of the pump.
25. Turn on power to the pump system, run the cylinder, and listen carefully to ensure that all motor sounds are normal.

11.4 Cooling Fan Maintenance

This section describes cooling fan maintenance for both the high temperature pump cylinders and the CMD-5000 Dual Controller Driver.

11.4.1 High Temperature Systems

Recommended Frequency—every 12 months of regular use.

On Quizix C-5000 High Temperature Pump Cylinders, the pump cylinder stepper motor has a cooling fan attached to it to prevent the motor from overheating. This fan operates when the motor driver in the CMD-5000 is on. It should have access to fresh air at all times. To determine if it is operating properly, do the following:

1. With the CMD-5000 Dual Controller Driver turned on, place your hand close to the cooling fins on the outside of the cylinder's stepper motor.
2. Verify that a steady flow of cool air is being forced over the cooling fins and that the fan is operating quietly, making only a steady, whirring sound.

11.4.2 CMD-5000 Fan

Recommended Frequency—every 12 months of regular use.

The CMD-5000 includes a thermostatically controlled fan. Because it is thermostatically controlled, it turns off automatically when air is not required for cooling. The CMD-5000 also has a set of large black cooling fins mounted to its top panel. The left side of these fins rise up perpendicular to the top panel, but the right side of the fins rise up at a 40° angle. Looking down from the top of the unit, the motor driver's cooling fan can be seen at the base of the 40° angled side of these fins.

When the fan inside the CMD-5000 is on, you will be able to feel air flow across the heat sink fins. You will also be able to hear the sound of the fan, which is a steady, quiet, whirring sound. Because the fan is thermostatically controlled, it will not operate continuously. You should ensure, however, that it does turn itself on and off automatically.

11.5 Replacing the Safety Rupture Disk

Recommended Frequency—every 2 years of regular use.

If you regularly operate your pump system at pressures in the range of 80 to 100% of maximum pressure (8,000–10,000 psi for a C-5000-10K pump cylinder system), note that safety rupture disks can weaken after extended use at these pressures. If you frequently operate at such high pressures, you should replace the safety rupture disks on a regular basis as part of their scheduled system maintenance. Alternatively, you may want to install safety rupture disks with a higher rating. In that case, contact Quizix for the appropriate specifications.

Safety rupture disks are installed to prevent the system from exceeding a specified pressure. (The terms safety burst disk (SBD) and safety rupture disk are used interchangeably in this manual.) The safety rupture disk is activated if there is a transducer failure that cannot be detected by the normal safety systems or in the extremely unlikely event of a hardware or software failure, in which the pump system does not respond to normal controls. In this situation, this disk protects the Quizix pump from damage.

The safety rupture disk included in Quizix pump systems is a *one–time only* item that must be replaced after it has been activated. It is not a pressure relief valve and cannot be tested. If the system pressure is brought to a level that activates the disk, it ruptures and must be

replaced. Refer to Chapter 5 for more information about safety rupture disks. Generally, the pressure at which the safety rupture disk activates should be slightly higher than the maximum pressure rating of the pump cylinders in your system. See Table 11-3 for the safety rupture disk rating used with each C-5000 pump cylinder model.

Table 11-3 Safety Rupture Disk Ratings

Cylinder Model	Maximum Operating Pressure	Safety Rupture Disk Rating
C–5000-2.5K	2,500 psi	3,500 psi
C–5000-5K	5,000 psi	6,500 psi
C-5000-L-7.5K	7,500 psi	10,000 psi
C–5000-10K	10,000 psi	12,500 psi
C–5000-L-10K	10,000 psi	12,500 psi
C-5000-20K	20,000 psi	25,000 psi

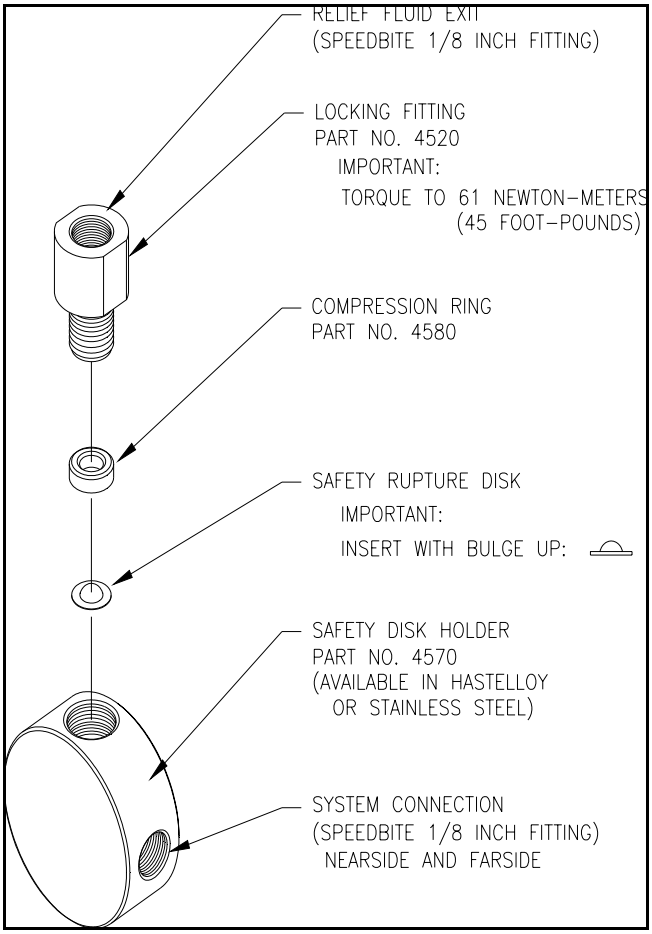

Figure 11-14 Safety Rupture Disk Assembly

To replace a safety rupture disk, use the following procedure.

1. Remove the safety rupture disk assembly from the pump system (this is an important precaution).
2. Unscrew the safety rupture disk locking fitting while securely holding the safety rupture disk holder.
3. Remove the locking fitting, compression ring, and the old safety rupture disk.
4. Carefully and completely clean out the seating area for the safety rupture disk in the safety rupture disk holder. Also, clean the new safety rupture disk and compression ring so that they are free of any dirt or contaminating particles.
5. Insert the new safety rupture disk into the safety rupture disk holder, making sure the bulge in the disk is outwards (convex).

NOTE: It is very difficult to see if the disk is convex or concave by looking at it. It is better to take a smooth rod and feel if the disk is in place so that the center is higher than the edges.

6. Place the compression ring on top of the safety rupture disk, then screw in the locking fitting.The compression ring is symmetrical, so it can be installed with either side down.
7. Screw the fitting finger tight and then use a torque wrench to tighten it to the torque specified on the metal tag attached to the disk. The torque depends on the pressure rating of the safety rupture disk.

The safety rupture disk assembly is now ready to be re–installed in the pump system.Be sure to also re-install tubing into the fitting of the relief fluid exit and plumb it to an appropriate receptacle.

The Spare Parts Kit included with each pump system includes one replacement safety rupture disk. Additional safety rupture disks are available in stainless steel or Hastelloy and may be obtained from Vindum Engineering (Quizix's sales agent).The safety rupture disk's type and model number is printed on the tag that is attached to it.

11.6 Calibrating the Pressure Transducers

The pressure transducers on the 5000 Series Pump System need to be recalibrated periodically. During normal use they should be recalibrated every 12 months. If usage is heavy, or if the pump has been subjected to unusual circumstances such as pressures above its rated pressure range, then recalibration should be performed. Also, pressure transducers should be recalibrated after being taken apart and put back together.

Calibration keeps the two individual pressure transducers (on two pump cylinders used as a pair) reading the correct pressure. The pump controller uses these pressures to match the standby pump cylinder's pressure to the active pump cylinder's pressure to eliminate pressure variations at switchover. If the two pressure transducers are not matched to each other, than the pressure in one pump cylinder will not be the same as the pressure in the other pump cylinder, even though the readings on the display will match. The easiest way to check if the pump cylinders are matched is to use one pump cylinder to pressurize both pressure

transducers (connect pump cylinders together) and record the pressure of both pressure transducers over the pressure range of interest.

11.6.1 What is a Pressure Transducer?

A pressure transducer is a device that converts a pressure to an electrical signal proportional to that pressure. In the CMD-5000 Series controller, the signal generated by the pressure transducer is sent directly to an A/D (analog-to-digital) converter which converts the analog electrical signal of the amplifier to a 20-bit digital signal that is displayed on the computer.

Each individual pressure transducer will have slight variations in zero pressure output voltage (zero offset) and its output voltage at full pressure (gain). In the 5000 Series Pump System these variations are compensated for in the controller software. The process of adjusting the offset and gain compensation values is called calibration.

11.6.2 Methods of Calibrating the Pump System

There are two basic methods of pressure calibration for all Quizix Pump Systems. The first method is to attach a secondary calibrated gauge, such as a quartz transducer, to the system. With this method, the pressure for the calibration procedure will be generated by the Quizix pump. Then the pressure read by the Quizix system is adjusted until the system's transducer readings match the reading by the calibrated gauge (CG).

The second method is to use an external pressure source, such as a "dead-weight tester." With this method the user connects the external calibrated pressure source (PS) to the pump system. The pressure is then read by the pump system and adjusted until it matches the pressure being output by the pressure source.

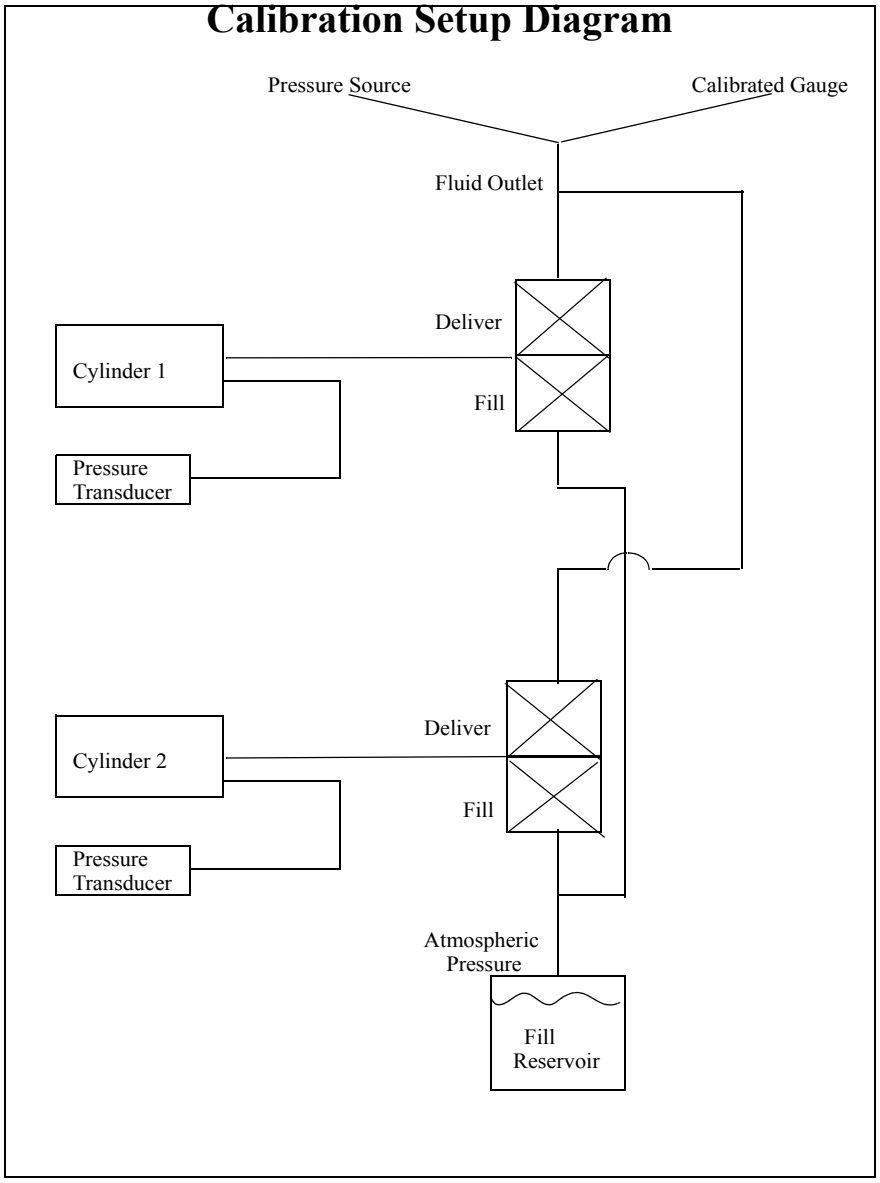

Figure 11-15

11.6.2.1 Calibrated Gauge Method

1. As shown in the Calibration Setup Diagram in Figure 11-15, connect a calibrated gauge (CG) to the fluid outlet of your Quizix Pump System. Be sure your fill valves are connected to a fill reservoir at atmospheric ("zero gauge") pressure.

2. Set the system to "zero gauge pressure" as follows: for the pump cylinder(s) being calibrated, open the fill valve(s) so the cylinder pressure is at atmospheric or "zero" pressure. The deliver valve(s) can also be opened, if desired.

3. Adjust the offset. Go to PumpWorks main window. From the menu bar select Other | Software Pressure Transducer Calibration. In the Software Pressure Transducer Calibration window, select "Current Offset". The easiest way to adjust the offset is to select "Auto Zeroing". Doing this will result in the computer calculating the necessary offset to have the display read zero pressure. The range of zero offset is limited so that a malfunctioning transducer or a transducer with significant pressure accidentally left on it, will not be able to be zeroed.

   Alternatively the user can compute the desired offset and enter this value into the appropriate box. With this option the user can have the display show a value other than zero pressure on the display when zero pressure is present. This can be used if absolute pressure readings are desired.

4. Set the pressure to 90% of the system's maximum rated pressure.

5. Set the safety pressure to 95% of the system's maximum rated pressure.

NOTE: If your system is typically operated at significantly less than the pump's maximum rating (for example, typical usage at 100 PSI for a 5,000 PSI pump), then the pressure in this step may be set at the system's typical operating pressure to obtain a more accurate calibration.

6. For the pump cylinder(s) being calibrated, open the deliver valve(s) and close the fill valve(s).

7. Use PumpWorks to set the pump cylinder you are calibrating to extend in Constant Rate Independent Mode (#1), at 1 ml/minute. Start the pump cylinder and monitor the pressure with the calibrated gauge.

8. Stop the pump when pressure reaches 90% of the system's maximum pressure.

IMPORTANT
When you raise the system's pressure, the temperature of the pump's internal fluid will temporarily rise. As this fluid cools, the system pressure will drop. In this situation it is best to wait five minutes after reaching your high pressure before proceeding, so that the pressure is not changing while you are trying to calibrate.

9. Adjust the gain. Go to PumpWorks main window. From the menu bar select Other | Software Pressure Transducer Calibration. In the Software Pressure Transducer Calibration window, select "Current Gain". The easiest way to adjust the gain of a pressure transducer is to enter the current pressure value into the Enter Known Pressure box. When this is done, PumpWorks calculates the necessary gain and adjusts the pressure reading to display this value automatically. Please remember to always adjust the offset prior to adjusting the gain.

   The user may also calculate the desired gain by hand and then enter the desired value into the software. The range of gains is limited to prevent faulty and malfunctioning

transducers from being calibrated and giving the illusion of working. For more information on calculating offsets and gains, see Section 9.1.3, "How to Calculate an Offset and Gain", in the PumpWorks User's Manual.

11.6.2.2 Calibrated Pressure Source Method

1. As shown in the Calibration Setup Diagram in Figure 11-15, connect a calibrated pressure source (PS) to the fluid outlet of your Quizix Pump System. Be sure your fill valves are connected to a fill reservoir at atmospheric ("zero gauge") pressure.

2. Set the system to "zero gauge pressure" as follows: for the cylinder(s) being calibrated, open the fill valve(s) so the cylinder pressure is at atmospheric or "zero" pressure. The deliver valve(s) can also be opened, if desired.

3. Adjust the offset. Go to PumpWorks main window. From the menu bar select Other | Software Pressure Transducer Calibration. In the Software Pressure Transducer Calibration window, select "Current Offset". The easiest way to adjust the offset is to select "Auto Zeroing". Doing this will result in the computer calculating the necessary offset to have the display read zero pressure. The range of zero offset is limited so that a malfunctioning transducer or a transducer with significant pressure accidentally left on it, will not be able to be zeroed.

   Alternatively, the user can compute the desired offset and enter this value into the appropriate box. With this option the user can have the display show a value other than zero pressure on the display when zero pressure is present. This can be used if absolute pressure readings are desired.

4. Set the pressure to 90% of the system's maximum rated pressure.

5. Set the safety pressure to 95% of the system's maximum rated pressure.

NOTE: If your system is typically operated at significantly less than the pump's maximum rating (for example, typical usage at 100 PSI for a 5,000 PSI pump), then the pressure in this step may be set at the system's typical operating pressure to obtain a more accurate calibration.

6. For the pump cylinder(s) being calibrated, open the deliver valve(s) and close the fill valve(s).

7. Set the pressure source to bring the pressure up to the desired level.

8. Adjust the gain. Go to PumpWorks main window. From the menu bar select Other | Software Pressure Transducer Calibration. In the Software Pressure Transducer Calibration window, select "Current Gain". The easiest way to adjust the gain of a pressure transducer is to enter the current pressure value into the Enter Known Pressure box. When this is done PumpWorks calculates the necessary gain and adjusts the pressure reading to display this value automatically. Please remember to always adjust the offset prior to adjusting the gain.

The user may also calculate the desired gain by hand and then enter the desired value into the software. The range of gains is limited to prevent faulty and malfunctioning transducers from being calibrated and giving the illusion of working. For more information on calculating offsets and gains, see Section 9.1.3, “How to Calculate an Offset and Gain” in the PumpWorks User’s Manual.

11.7 Valve Maintenance

For complete information on servicing the CV–210 and CV–310 valves on the Quizix 5000 Series Pump System, refer to *The CV–210 and CV–310 High Pressure Valves User’s Manual* from Vindum Engineering, which was shipped with your pump system.

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12 TROUBLESHOOTING

This chapter will help the user solve problems they might encounter when operating their pump. It is divided into the following areas.

- Troubleshooting Basics, Section 12.1
- PumpWorks Error Messages, Section 12.2
- CMD-5000 Two Digit Display Error Messages, Section 12.3
- Other Pump Troubleshooting Situations, Section 12.4
- Software Updates, Section 12.5

12.1 Troubleshooting Basics

In 5000 Series Pump Systems with two or more pump cylinders, the pump cylinders can be compared to each other in order to isolate the cause of some problems. Also, the removable parts of the pumps are interchangeable and can also be used to help isolate the cause of a problem. The removable parts include the cylinder barrels, seals, pistons, transducers and valves. Note that the transducers can be interchanged, but will require recalibration if this is done. An example is pump cylinder A is leaking, and continues to leak after replacing the seal. The user needs to determine if the problem is the cylinder barrel or the piston. To find out, a user could exchange the cylinder barrels between pump cylinders A and B. If the leak moved from pump cylinder A to pump cylinder B, then we know the problem is either the cylinder barrel or the seal that is inside of the cylinder barrel. If, however, the leak continued coming from pump cylinder A, then we know there is a problem with the piston, such as a scratch or hard deposit.

When trying to figure out the cause of a problem within the 5000 Series Pump System, there are several PumpWorks features that could give the user more information. They are:

- **Current System Status Window**
  The Current System Status window, located on the Error/Log menu, shows the current state of all pumps being controlled by PumpWorks. Items in green indicate that no errors are present and items in red indicate that an error is present. Errors that do not apply are grayed, as well as pumps that are not installed. For ease of viewing, pumps 1 through 4 are shown in one window, while pumps 5 through 8 are displayed on a separate window.

- **Error Log**
  PumpWorks maintains a log of all errors. Each error entry consists of the date and time the error occurred, as well as a description of the error. The most recent errors are displayed in the Current Errors Log. The Previous Errors Log maintains a list of all errors, present and past, that have been detected by PumpWorks up to a maximum file size set by the user.

- **Physical Piston Position Indicators**
  Every C-5000 Pump Cylinder has side covers which allow the user to view the piston's position. The side covers on ambient temperature cylinders are clear acrylic panels through which the ball screw can be viewed. The side covers on high temperature cylinders are black anodized aluminum with a slot cut into them for viewing. The user can watch the piston move all along its stroke, from its Max Retract position to Max Extend position (or vice versa).

- **Cylinder Switch Status Window**
  The Cylinder Switch Status is located on PumpWorks Error/Log Menu. This window displays the current readings obtained from the motion sensor board of the pump cylinders. The sensor board indicates the position of the piston. The Cylinder Switch Status window is useful if there is an error message related to the piston position control switches. For a complete description of this feature, see Section 10.5 of the PumpWorks User's Manual.

- **Error State Capture Mode**
  In Error State Capture Mode, the user can view an instant replay of the conditions of the pump before and after an error occurred. In the same way that a video camera can capture an event, PumpWorks can capture an error. If an error occurs, PumpWorks records the error and all pump operating information. The captured information is saved to the computer's hard drive from 180 seconds before until 30 seconds after the error occurred. This data can then be viewed by switching to the Error State Capture Mode, located on the Error/Log menu.

  Once in Error State Capture Mode, the user double clicks on an error in the Previous Errors Log. "Control Error State Capture" then becomes an option on the Error/Log menu. Control Error State Capture is used to scroll through the error transactions so the user can view the flow rates, pressures and volumes the pump was reporting before and after the error occurred.

  The Error State Capture Mode data is stored in two files, Pumpworks.est and Quizix.erl. These two files, plus the Pumpworks.ini file, contain the complete error information. By viewing the data in the Error State Capture Mode, the user can usually figure out what has gone wrong. In the event of a problem that the user cannot figure out, these three files can be sent to Quizix and used to help figure out what caused the error.

  Please refer to the PumpWorks User's Manual for more information about Error State Capture Mode.

12.2 PumpWorks Error Messages

When PumpWorks recognizes that an error has occurred in the pump system, an error message is generated. "Errors Present" will appear against a red background on the status bar. The Current Error Log, which is located on the Error/Log menu, will list the error date, what time it was when the error occurred and give a description of the error. The error will also be recorded in the Previous Error Log, where a list is maintained of all errors, present and past, that have been detected by PumpWorks (up to a maximum file size set by the user).

Some errors are “immediate errors” and some are “logged errors”, which we will discuss in the following sections.

12.2.1 Immediate Errors

An Immediate Error is generated in response to a command sent by the user. This is generally the result of a user asking the pump to do something that is not permitted. An example is trying to open or close a valve, or change the operating mode of a pump cylinder that is currently running. A dialog box immediately appears on the screen with an error message. The text in the dialog box clearly explains what prevents the requested action from being executed.

An immediate error is NOT logged to the Current Error Log or the Previous Error Log. The status bar of the PumpWorks main window reads “No Errors” and the motion status display does not show an error status for that pump cylinder.

12.2.2 Logged Errors

A logged error is entered into the Current Error Log and Previous Error Log, but no dialog box appears on the screen. The status bar of the PumpWorks main window displays Error Present or Check Error Log. Most logged error messages are very easy to understand and the user is able to correct the problem quickly. An example of a logged error is “Error Over Pressure on Cylinder 1A” This means that the safety pressure in pump cylinder 1A, set by the user, was exceeded by the pump cylinder and caused a digital overpressure error. This error would cause an operating pump to stop.

While most logged error conditions are self-explanatory, some are explained in additional detail below.

12.2.2.1 Soft Limit Warning

A soft limit is a stroke position that is outside the normal operating stroke area. A soft limit warning is usually the result of the pump not being able to adjust quickly enough to an operating condition. A soft limit will not stop pump operation. For example, if a pump is maintaining pressure at max extend and the pressure suddenly drops, the pump will extend a little further than it would normally and enter the soft limit. If a soft limit is reached, the pump controller’s software keeps the pump operating only in the direction away from the soft limit. Since the piston stroke is very limited at this point, some variation in pressure or flow rate may occur. Soft limit errors do not cause damage to a pump and will not stop a pump’s operation. If a soft limit occurs, however, the user should try to determine the operating conditions that led to this error in order to avoid a soft limit error in the future. To move a pump cylinder out of the soft limit area, use Independent Constant Rate mode.

12.2.2.2 Communication Errors

In order for PumpWorks to control a user’s pump system, communication needs to be established between the user’s computer and pump(s). The following communication errors are covered in the sections below:

- Communication Cannot Be Established, Section 12.2.2.2.1
- Once Communications Has Been Established, Section 12.2.2.2.2

12.2.2.2.1 Communication Cannot Be Established

If communication cannot be established between the pump and PumpWorks, do the following:

- First, check the two digit display labeled "Pump Number" located on the pump controller. There is a right digit decimal point, which is located to the right-hand side of the right digit. There is also a left digit decimal point, which is located to the right-hand side of the left digit. The right digit decimal point flashes when signals are being transmitted from the computer to the pump controller. The left digit decimal point flashes when signals are being transmitted from the pump controller to the computer. When viewing the two digit display a user should see both decimal points flashing. If the decimal points are not flashing, there may be a break in the communications cable which carries the signal between the pump and the computer.
- Next check that the computer is properly connected to your pump. To do this, perform the PumpWorks Connection Check found in Chapter 3, Section 3.2.
- Go to PumpWorks main window. From the menu bar, select Communications | View Communication Status.

  After a few seconds the "COM Port Selection for Communication Status" window appears. Click on the COM number that your pump system is connected to, then click on OK.

  The PumpWorks Communication Status for Com # window appears. At the top left corner check to see if the serial expander/isolator is present or not present.

  If the expander is present, the problem is between the serial expander/isolator and the pump controller.

  - Check that the data link cable is plugged into "Data Link" on the pump controller and NOT into "Front Panel".
  - Try plugging the pump controller into a different port on the serial expander/isolator. Ports A, B, C or D are possible. Search for pumps again by selecting Communication | Search For Pumps.

  NOTE: Each time you alter any item during this troubleshooting process you need to search for pumps so that PumpWorks can establish communication with the pump(s).

  If the serial expander/isolator is NOT present, then the problem is between the computer and the serial expander/isolator. Check the RS-232 cable, try a different serial port on the computer, or try using a different computer.

12.2.2.2.2 Once Communications Has Been Established

Once communications is established between PumpWorks and the pump controller, the following communication errors may be reported in the error log. These errors are automatically compensated for by PumpWorks, which notes the error and then resends the command again so that no data is lost. If a lot of these errors are occurring, then communication between the pump controller and PumpWorks is significantly slowed down. It is therefore better to discover and correct the source of these errors when possible.

- **Buffer Overrun Error**
  Buffer overrun errors are due to a slow computer. This can be corrected by keeping other programs from operating while using PumpWorks, or by getting a faster computer. When a buffer overrun error occurs, PumpWorks automatically retries and corrects for any dropped communications.

- **CRC Check Error**
  CRC check errors mean the communication line is noisy. Either the data communications cable is too long or it is placed next to a source of electrical interference. Correct the problem and the error should go away. If the CRC check errors continue, however, either the computer's serial port, the serial expander/isolator or the pump is not working on the proper frequency. Try using a different serial port on your computer or a different computer.

- **Incorrect Number of Bytes Received**
  Incorrect number of byte errors can be caused by a slow computer or by a noisy communication line. Noisy lines can be caused by the data communications cable being too long or being too near a source of electrical interference.

- **Input Error**
  Input errors are due to a bad command being received by the pump. Noisy communication lines are normally the cause of this type of error. If an input error occurs, PumpWorks automatically retries and corrects for any dropped communications.

- **No Response from Pump Error**
  This error is most likely caused because the computer is busy with another task. This can be corrected by keeping other programs from operating while using PumpWorks, or by getting a faster computer. When PumpWorks receives no response, it automatically retries and corrects for any dropped communications. It should be noted that the Windows 98 operating system is particularly bad at being able to properly handle communications at times. We can only hope that Microsoft's next operating system will be better.

12.3 CMD-5000 Two Digit Display Error Messages

The CMD-5000 Dual Controller Driver has a two digit display which is labeled "Pump Number". The two digit display relays information concerning the pump's status. Using either letters, numbers or a combination of the two, the digital display can convey the following errors:

- analog overpressure errors,
- communication errors,
- digital overpressure errors,
- digital underpressure errors,
- driver fault errors,
- malfunctioning controller or power supply, or

- the absence of a motor, sensor or transducer and valve cable.

If no errors are present, the two digit display will display the pump number (1,2,3, and so on).The following two digit display errors are discussed in this section:

- The Two Digit Display Does Not Light, Section 12.3.1
- The Two Digit Display Does Not Complete Its Initial Check., Section 12.3.2
- Pump Controller Diagnostics, Section 12.3.2.1
- Pump Controller Software Initialization, Section 12.3.2.2
- Two Digit Display Error Code, Section 12.3.3

12.3.1 The Two Digit Display Does Not Light

If the two digit display does not light when power is turned on to the pump controller, do the following:

- Check that the power cord is fully plugged in.
- Check that power is available to the electric outlet.
- Try turning the pump controller's power switch off and then back on again.

  If the two digit display still does not light, either the power supply or the pump controller has failed and needs to be replaced at Quizix. The fuse for the power supply may need to be replaced. See Chapter 10 for instructions on replacing a fuse.

12.3.2 The Two Digit Display Does Not Complete Its Initial Check.

Each time a segment of the two digit display lights during the initial pump start-up, a specific aspect of the pump controller is being checked. If the two digit display fails to complete its initial pump start-up check, that is an indication that the pump controller's printed circuit board needs to be replaced at Quizix.

Watch the two digit display when you turn on your pump.

- The first thing that will happen is all segments of the display will light at once, briefly.
- Next, the display should flash the boot version number (currently version 3.6).

12.3.2.1 Pump Controller Diagnostics

The basic pump controller diagnostics are performed next. The controller begins testing itself. If a test fails, the display will freeze. Report this to Quizix technical support.

The right hand digit will light, the left hand digit will not. One segment of the right hand digit will light at a time, starting with the top segment as shown in Figure 12-1 below. One segment lights, then a second segment lights, then a third, and so on. Each segment that lights is a confirmation from PumpWorks that a specific aspect of the pump controller is operating correctly.

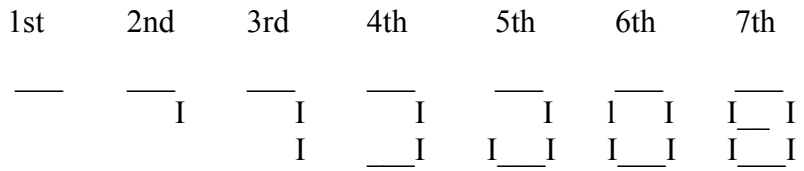

Figure 12-1

The segments on the right hand digit represent the following tests performed by the pump:

Segment 1: RAM test OK

Segment 2: Move code OK

Segment 3: Boot CRC OK

Segment 4: Block 1 CRC check

Segment 5: Block 2 CRC check

Segment 6: Block 3 CRC check

Segment 7: Code CRC OK, Jump to program

If segments 1, 2, or 3 do not light, call Quizix.

If segments 4,5,6,or 7 do not light, start PumpWorks and load the program code. PumpWorks will know that the program is bad and will prompt the user for the program file name.

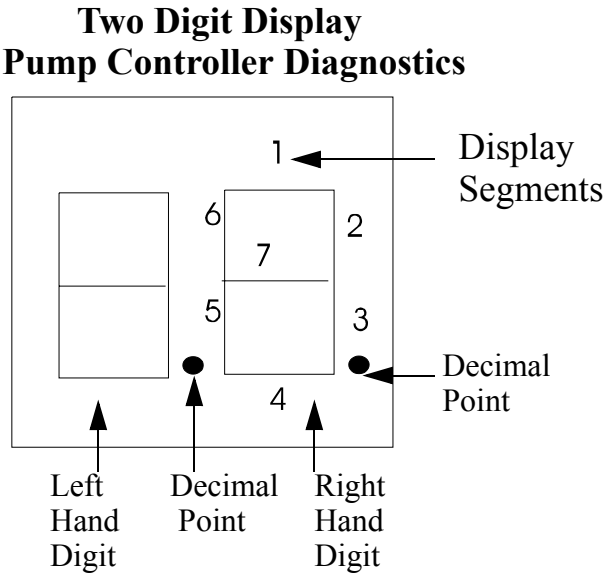

Figure 12-2

12.3.2.2 Pump Controller Software Initialization

The pump controller software initialization is performed next. The left hand digit will light, the right hand digit will not. The left hand digit will display number 1, then 2, then 3, then 4, then 5, then 6, then 7. Each number that lights is a confirmation that a pump controller software function is operating correctly. The numbers will flash quickly.

The numbers on the left hand digit represent the following tests performed by the controller's software:

0,1,2 = load program into RAM and initialize variables

3,4 = calibrate pressure channel A to D for cylinder A and B

5,6 = check and set pump cylinder location for cylinder A and B

7 = all tests passed, accept commands from PumpWorks

In the final step, "do" will flash alternately with "0". The "do" stands for digital overpressure. As a safety precaution each time a pump system is powered on, the safety pressure is set at -50 PSI. The user must set the safety pressure to a valid operating value each time the pump system is powered up. The "0" means the pump has not yet been assigned a pump number by PumpWorks. As soon as the pump is installed onto PumpWorks, the "0" will be replaced with the pump number.

12.3.3 Two Digit Display Error Code

Following is a list of letters that can appear on the two digit display, written in block style. A brief definition follows each error code.

AO Analog Overpressure Error
- pressure transducer signal abnormally high
- transducer or transducer cable failure
- analog to digital converter problem

CE Communication Error
- unable to decode communication from computer

DC Driver Cable Error
- driver cable not connected

DE Driver Status A or B
- the motor driver has a fault--possibly overheated or shorted
- turn off power to reset driver

DO Digital Overpressure Error
- cylinder pressure exceeds safety pressure (When a pump is powered on, it will have this condition until the safety pressure is set.)

DP Driver Power
- the motor power supply has shut down
- turn off power to reset power supply

DU Digital Underpressure Error
- pressure transducer signal abnormally low,
- transducer or transducer cable failure,
- analog to digital converter problem

ES E Stop
- user has activated the emergency stop signal on the user interface connector

LE Low Side Driver Error
- a valve wire is not connected (pilot solenoids on valves)

PC Pressure Transducer Cable Error
- pressure transducer cable not connected

PE Motion Error (Position Error)
- malfunctioning linear motion sensor
- drive train problem--slipped gear or ball screw problem

SC Sensor Cable Error
- sensor cable not connected

SL Soft Limit Warning
•stroke position outside normal bounds
•malfunctioning motion sensor

UC Valve Cable Error
• valve cable not connected

To correct cable errors, locate the cable that the problem is reported on and make sure it is fully plugged in. For driver or power supply shutdown error, try powering the pump off and then back on. These devices have overload protection circuits that shut them down when overloaded and are reset when powered on.

12.4 Other Pump Troubleshooting Situations

Most error messages are very easily understood and resolved. Some pump conditions either do not generate an error message or are more complicated to diagnose. Below are some pump situations that may occur.

- Air Supply Problems, Section 12.4.1
- Fan Does Not Run, Section 12.4.2
- Fluid Leaks, Section 12.4.3
- No Fluid Is Being Delivered, Section 12.4.4
- Piston Motion Errors, Section 12.4.5
- Pressure Problems, Section 12.4.6
- Valve Problems, Section 12.4.7

12.4.1 Air Supply Problems

The valves on the 5000 Series Pump System need a CLEAN, DRY air supply, between 4.5 and 6.9 bar (65 to 100 PSI) to properly operate.

12.4.1.1 No “Air Escaping” Sound When Valves are Opened and Closed

The most likely cause of this problem is that the air supply is not dry, so the pilot solenoids have rusted and stopped switching. To check this, turn off your air supply, unplug your air line and check if there is any water in the line. If the pilot solenoids have rusted and no longer operate, they will need to be replaced.

The other cause of this type of problem is the air pressure is too low or too high to operate the valves. Use a pressure gauge to determine the air pressure. If the air pressure is too low:

- Check that your air tubing has been connected properly,
- Check that the air supply is on, and
- Check that the air tubing is not clogged.

If the air pressure is too high (more than 6.9 bar (100 PSI)), install an air regulator to limit the pressure.

12.4.1.2 Constant "Air Escaping" Sound

If you hear a constant "air escaping" sound when the valves are not being operated, then it is likely there is an air leak. The pilot solenoid valves should not leak air when they are operating properly.

- Check each air fitting to see if any fitting is loose.
- Check each air tube to see if it is cracked.
- Try using "Snoop" (soap and water solution) to detect small leaks by making bubbles appear.
- Sometimes a pilot solenoid will get stuck part way open or part way closed and allow air passage. Try opening and closing the valve to get the pilot solenoid unstuck and moved to a fully open or fully closed position. Opening and closing a pilot solenoid a few times may free up a stuck solenoid. If this doesn't work, the pilot solenoid may have to be replaced so it does not constantly leak air.

12.4.2 Fan Does Not Run

Ambient temperature pump systems do not have a fan connected to the pump cylinder, while high temperature pump systems do. On high temperature versions of the C-5000 pump cylinder the fan must ALWAYS be running when the pump cylinder is operating. If the fan does not come on when the CMD-5000 is powered on, or if it stops while the pump is running, stop the pump cylinder immediately. Contact Quizix for a replacement fan.

12.4.3 Fluid Leaks

Although Quizix pumps are made to a high standard, a fluid leak can occur. The following sections explain what to do if you have a fluid leak.

- Leakage Basics, Section 12.4.3.1
- Leak Testing, Section 12.4.3.2
- Does Your Pump Have a Fluid Leak?, Section 12.4.3.3
- Finding Your Leak, Section 12.4.3.4

12.4.3.1 Leakage Basics

The SP-5000 is a pump system that uses a piston to push fluid out of a cylinder barrel. The fluid is contained in the cylinder barrel by a seal, which has a static connection to the cylinder barrel and a dynamic (moving) interface to the piston. For a continuous flow system, valves, pressure transducers and interconnecting tubing and fittings are also required to control the flow of fluid. Any of these components can be the source of a fluid leak.

Detecting a leak can sometimes be difficult. Large leaks in the range of 0.01 ml per minute are easy to find since these can be observed by the eye (a typical drop of liquid is about 0.05 ml) or detected with a bubble (snoop) leak detection solution for gases. Smaller leaks in

the.01 to.001 ml per minute range become more difficult since fluid can evaporate as fast as it leaks. Care and patience are needed to find leaks in this range. If you are using brine, a salt deposit residue is a clear indication of a leak. Extreme care must be used to find leaks below 0.0001 ml per minute, since many other factors need to be considered.

12.4.3.2 Leak Testing

The 5000 Series Pump System can trace volume changes very accurately. This volume measurement, combined with the pressure measurement, can be used to detect fluid leaking from the pump system.

- To detect a leak in this way, the pump cylinder can be pressurized to a set pressure and then stopped, and the pressure can be recorded as a function of time. This is a truly static leak test in that the piston is not moving with respect to the seal.
- Alternately, the pump cylinder can be operated in constant pressure mode and the volume recorded versus time. This is a quasi-static method in that the piston will be making slight motions as the pressure control algorithm operates.
- A third method uses gear mode, without valves, to push fluid from one pump cylinder into the other. This is a truly dynamic leak test of the pump cylinders.

Temperature must be precisely controlled in order to know if a small leak is real or not. Depending on the compressibility and fluid used, temperature changes cause variation in pressure in a closed fluid system. In a typical pump cylinder, pressure can change 50 to 100 PSI per degree C. Therefore, if you want to detect small leaks, temperature must be held steady, and even then long tests are usually needed to get reliable data.

Not only does external temperature need to be controlled, time must be allowed for thermal equilibrium of the fluids in the pump system. When a fluid is pressurized, it heats up. This heated fluid inside the pump cylinder then starts to cool down to the cylinder barrel temperature. As it does this, the fluid contracts and the pressure falls. This fall in pressure can look like a fluid leak. Allow at least 15 minutes after pressurization for the temperature to equalize.

When looking for small leaks, there are several other considerations to be aware of. The seals and o-rings in the system are elastic. With pressure and time they tend to creep, which increases volume in the cylinder barrel and looks like a fluid leak. This problem is most noticeable when a new seal or o-ring is installed, but can also show up in dynamic tests as the seals and rings wear and lose material to the outside.

Other factors that can affect the results of leak tests include pressure transducer drift, fluid property changes, gas bubbles, and fluid permeation or absorption into the seals and o-rings.

12.4.3.3 Does Your Pump Have a Fluid Leak?

A pump cylinder can be checked for fluid leakage by following the steps below:

1. Fill the pump cylinder with the fluid to be tested
2. Set the pump cylinder to constant pressure independent mode.
3. Close both the fill and deliver valves.
4. Select an appropriate test pressure.

5. Start the pump cylinder.

Next the pump will pressurize and hold the set pressure. After allowing for thermal effects to subside (about 15 minutes) set the volume of the pump cylinder to zero and watch for fluid volume changes. If the pump continues to move forward, then there is a leak. By logging the volume versus time, the leak rate can be determined. Any changes in temperature during this test time will also show up as changes in volume, so care must be used in analyzing this data.

12.4.3.4 Finding Your Leak

If you detect a leak, then the next step is to find it. The most likely places for a leak to occur are at the piston-seal interface or in the valves. Seal leaks are most often caused by particles in the fluid scratching the lips of the seals. If fluid is leaking out of the bottom of your pump cylinder, you are very likely to have a seal leak. If a fluid leak is present and no evidence of fluid leakage is present at the valve leak ports, or around any of the fluid tubing fittings, then most likely there is a seal leak. To test more thoroughly, try removing the fitting at the front of the cylinder barrel and replacing it with a plug, then running the leak test again. If you still have a leak, then it is almost for sure a piston seal leak. Please refer to Section 11.2 "Changing the Cylinder Barrel Seals". If the leak is no longer present when this test is run, then the leak is most likely in the valves.

Seals generally will have a lifetime of about 1 year. With certain fluids, seal life decreases. To increase the life of the seals, the following can be done:

- Pump clean fluids whenever possible.
- Filter the fluid being pumped so there are few, if any, particles in the fluid.
- If you are pumping brine or other corrosive fluid, do not let it sit in the pump for a long time. Flush the pump with a clean fluid after each use.

12.4.4 No Fluid Is Being Delivered

If no fluid is being delivered during pump operation, try the following:

- Make sure the fluid inlet plumbing is connected to a fluid source. If using an inlet filter, try removing it temporarily.

- Check if the fluid inlet or fluid outlet plumbing is clogged, resulting in no fluid entering the pump. If you suspect a clog, disconnect the tubing and check that fluid can easily flow through the tube in question.

- Check for loose fittings on the fluid inlet side. Check to see if the tubing has a hole or crack which would cause air to be drawn into the tube instead of fluid.

- Check to see if the fluid is too viscous, or thick, to be pulled into the pump. This can be checked by watching the pressure of the pump cylinder as it starts to fill. If the pressure drops too much, the fluid will cavitate and not get pulled into the pump. Typically

pressure drops only 1 to 2 PSI when the pump cylinder is pulling in fluid. Water will cavitate if the pressure during filling drops more than 6 PSI.

- Check the motion of the piston by doing the following:
  1. Set the operating mode to Independent Constant Rate.
  2. Set the flow rate to 50% of the maximum flow rate of the C-5000 model you are using.
  3. Set the cylinder direction to either extend or retract, whichever is appropriate.
  4. Open the fill valve.
  5. Start the pump cylinder and watch the physical piston position indicator through the side cover for proper movement from max retract to max extend. If there is no piston movement, contact Quizix technical support.

- Make sure the valve assembly is installed in the correct position and that all valve fittings are securely tightened.

- Check the transducer and valve cable. Make sure it is properly connected to both the transducers and the pilot solenoids. Check that the fill and deliver valves are operating properly by performing the "Valve Check" in Section 3.2.

- Check that the air pressure for the valves is between 60 and 100 PSI. If the air pressure is too low or too high, the pilot solenoids can malfunction.

- Is the air clean and dry? The pilot solenoids are constructed of soft magnetic iron and can easily rust when exposed to moisture.

12.4.5 Piston Motion Errors

In most cases, piston motion problems will cause PumpWorks to report a piston motion error. If a motion error occurs, the user needs to determine if the piston is actually moving or not. This is done by looking through the pump cylinder side cover. The following piston movement errors will be discussed in this section:

- Motor Running, No Piston Movement Detected Error, Section 12.4.5.1
- Motor Stall Error, Section 12.4.5.2
- Piston Moves, But Does Not Complete Its Stroke, Section 12.4.5.3

12.4.5.1 Motor Running, No Piston Movement Detected Error

A Motor Running, No Piston Movement Detected error is generated when the motor is running but no motion is detected by the sensor board. This can be caused by a motor stall or faulty motion sensor. To check these conditions, start the pump cylinder and watch the physical piston position indicator through the side cover.

- Double-check that you are watching the physical piston position indicator for the pump cylinder that has been started on PumpWorks. For example, if you started Cylinder 1A, then make sure you are looking through 1A's side cover.
- Make sure that the flow rate that the pump cylinder is operating at will provide observable motion. Take into account the flow rate units, either ml/hour or ml/minute.
- If the piston still cannot be observed moving through the side cover, contact Quizix technical support.

12.4.5.2 Motor Stall Error

A motor stall error occurs when the power needed to move the piston exceeds what is available from the motor. The motor then slips, with a fast, zipping noise.

If the cylinder direction was extend, then:

- Check if the current pressure exceeds the pump's maximum pressure.
- The piston may not be fully seated into the ball screw and has hit the top of the cylinder barrel.
- The ball screw drive may be blocked by something.
- Motor or driver may be malfunctioning.

If the cylinder direction was retract, then:

- Motor or driver is malfunctioning.

12.4.5.3 Piston Moves, But Does Not Complete Its Stroke

If the piston is moving normally in most of the operating range, but gets stuck at one end or the other, then check the following.

- The piston and piston holder may not be fully tightened into the end of the ball screw.
- The motion of the ball screw drive may be blocked by a foreign object.
- The seal back-up ring may have clamped down on the piston causing excessive friction.
- The motion sensor may be malfunctioning.

12.4.6 Pressure Problems

The pressure transducers on the 5000 Series Pump System are essential for proper pump operation. Any problem with the transducer will mean that the pump will not operate the way it is supposed to. Several types of problems with the pressure transducers are covered below.

12.4.6.1 Pressure Transducer Errors

If the pump reports a pressure transducer cable error, this means that the cable from the pump controller to the transducer is no longer connected properly and needs to be fixed. To correct this problem, do the following:

- The transducer and valve cable must be inserted into the transducers properly. Check the 6-pin circular connector at each transducer.
- Check if the cable has been worn or cut. If there is an analog overpressure or digital underpressure reading, this can be the result of a controller failure, a transducer cable problem or a transducer failure.
- Check the transducer cable first and then try swapping transducers and transducer cables. If there is a faulty component, it will need to be replaced.

12.4.6.2 Pressure Does Not Increase Within 30 Seconds

If the pressure does not start to increase in a pump cylinder when it is running, then the most likely cause is no fluid in the pump, which can be caused by any of the following:

- A leak in the inlet fluid tubing allowing air to be pulled into the pump cylinder instead of fluid.
- The fluid inlet tubing is clogged, preventing fluid from entering the pump cylinder.
- Fluid is too viscous, or thick, to be pulled into the pump.

Other causes of this problem could be that the fill valve is leaking, the cylinder seal is leaking, the pressure transducers are cross wired or the fluid being delivered is leaking out some where in its fluid path.

Open the fill valve and listen for pressure being released. If there is pressure being released, you probably have a pressure transducer failure. NEVER operate the system AT ALL if you have any reason to believe a transducer has failed.

12.4.6.3 Pressure Overshoots Setting in Constant Pressure Mode

Pressure control in a constant pressure mode is set by the proportional and differential gain constants. Please refer to the PumpWorks User Manual to learn how to set the servo gains for desired pressure operation. This problem can also be caused by having a gas-liquid mixture. The piston will accelerate to compress the mixture and shoot past the set pressure before it can slow down. If you must use a gas-liquid mixture, you will need to carefully set the servo constants to keep the pump from exceeding the safety pressure.

12.4.6.4 Pressure Is Not Constant in Constant Pressure Mode

Pressure control in constant pressure mode is set by the proportional and differential gain constants. Please refer to PumpWorks User Manual to learn how to set the servo gains for desired pressure operation.

12.4.7 Valve Problems

The air actuated flow control valves are a vital part of the operation of the 5000 Series Pump System. They control the direction of the fluid flow. The valves used on the pump system are highly reliable. However, as with any mechanism, problems can occur. In this section we will present some basics on how the valves are used in the pump system. Refer to the Vindum Engineering Valve User Manual, included with your pump, which has detailed maintenance and troubleshooting information regarding the valves.

12.4.7.1 Valve Cable Connection Check

The transducer and valve cable connects the pump controller to the pilot solenoids. Make sure each cable branch with a 2-pin connector is properly connected to the pilot solenoid with the same number.

12.4.7.2 Checking Your Air Supply

The valves used in Quizix pump systems are air actuated. Air is taken into the system through the air inlet and distributed to the pilot solenoid manifolds. The pilot solenoids then distribute and control the air flow to the valves.

Nylon tubes connect the pilot solenoids to the valves. Check the tubing for cracks, clogs, or other problems. Check the color-coded fittings at both ends to be sure they are properly connected; the colors should match the fittings at both ends of the tubes.

12.4.7.3 Air Supply Requirements

IMPORTANT: Although the 5000 Series Pump System uses very little air, the air supply that is used **MUST** meet the following conditions:

- The air must be clean.
- The air must be dry. Moisture in the air supply will cause the pilot solenoids to rust and malfunction.
- The air must be between 65 to 100 PSI (4.5 to 6.9 bar). If air pressure exceeds this, the pilot solenoids may stop working.

12.4.7.4 Checking Your Air Supply Connection

To check the air supply connection, first identify the air inlet. Make sure a 1/4" tube is inserted into the air inlet fitting, and that it is tight and cannot be moved. Attached to the other end of the tube should be your pressurized air source. If your air supply has a switch to turn it on, make sure it is turned on so that air will be supplied to the pump. Note that 6 mm tubing will also work, in most cases. Nylon tubing is the recommended material for the air tubes, however, other materials will work.

12.4.7.5 Pilot Solenoid Check

Pilot solenoids are used to open or close the fluid pathways inside the valves. The pilot solenoid manifold takes in air from the user's air supply and distributes that air to the pilot solenoids. Please refer to Chapter 3, Section 3.2 for information on checking your pilot solenoids.

12.4.7.6 Clogged (Obstructed) Valve

It is possible for the valve inlet to become clogged with particles from the fluid being used. If a valve becomes clogged, then fluid can no longer be pulled into a pump. This can be detected by watching the pressure in the pump cylinder as the piston retracts. The pressure should not drop more than 1-2 PSI. If it drops more than this, the fluid may not be getting into the pump cylinder due a clogged inlet tube or valve. The outlet side of the valve is unlikely to clog due to the fact that the pump can generate high enough pressures to push most particles out of the valve. It may be possible to clear a clog on the inlet side by using the pump to push the particles out of the inlet. It would be advisable to clean all tubing and components thoroughly if a clog has been encountered so that this problem does not reoccur.

12.4.7.7 Valve Leaks Fluid When Closed

There is a possibility that the valve will not fully close and fluid can leak across the closed valve. If this occurs, the valve will not hold pressure. If you pressurize a pump and it is not holding pressure, fluid may be leaking out of a seal, or it could be leaking out across the valve. One way to check if a valve is leaking fluid is to swap valve A and valve B. Refer to the Valve User Manual for maintenance and repair instructions.

12.5 Software Updates

The operation of the 5000 Series Pump System is controlled by two separate software programs: PumpWorks 95-NT, which is stored on the user's computer, and the pump controller software which is stored in the CMD-5000 Dual Controller Driver. New versions of software are periodically released. Problems detected after a software version is released, are resolved in later software versions.

To make sure you have the latest software version available for your pump, check which version you have. Go to PumpWorks main window. On the main menu bar select Help | About PumpWorks. The version of PumpWorks 95-NT that is installed is displayed in the top center box after the words "Software Version". This software runs on the computer and is what you see on the computer screen and interact with.

The pump controller is also running a program. The controller software version is shown next to "Controller Version". The last two digits are a special part of the controller software called the "boot code". The rest of the digits are the controller software version. Next you need to check which is the latest version of the pump controller available. To do this contact Quizix, either by phone or by going to our website at: http://www.Quizix.com. Please refer to the PumpWorks User's Manual for software update procedures.

GLOSSARY

AC line noise rejection	This term refers to the reduction of the magnitude of voltage spikes and noise on an AC power line. Some uninterruptible power suppliers and surge suppressors are able to reduce voltage spikes and noise to help protect the electronic equipment connected to them.
A/D converter	An A/D (analog to digital) Converter takes an analog electrical signal and converts it to a digital signal that can be displayed as a number. An example would be to take an electrical signal from a pressure transducer and convert that signal so the pressure is displayed as a number on the computer.
acoustic separator	This is a device that uses ultrasonic signals to measure fluid volume. PumpWorks software allows for the pump system to interface with an acoustic separator.
activated	To put into action, or, to start working.
active pump cylinder	The pump cylinder that is delivering fluid to or receiving fluid from a users experiment. The deliver valve must be open and the fill valve closed.
active wash area	A wash area with both internal and external o-rings installed, that is capable of containing wash fluid.
adjustable face spanner wrench	A tool, supplied with your system, that is used to loosen and tighten the cylinder barrel retaining ring, and remove or install the seal retaining nut.
aflas	An elastimer seal material used in high temperature systems. Aflas works especially well with oil industry fluids.
air actuated	The operation is begun by a force of air. This is sometimes referred to as pneumatically actuated.
air inlet	The connection port where the user's air supply comes into the pump system.
air supply	Either an air compressor or bottled gas, supplied by the user, for operating the air actuated valves.
Allen wrench	This tool is used to tighten or remove six sided Allen-head screws. It is also known as a hex wrench.
Allen-head screw	This is a screw with an indented six sided head. It is also known as a socket head cap screw.

ambient temperature	Temperature that is equal to the temperature in the surrounding room.
amplifiers	A device which increases the magnitude or amplitude of a signal, such as voltage from a pressure transducer.
angle base plate	A metal plate, thicker on one side, that is mounted below the pump cylinder and supports the pump housing when it is resting on a table. The angle base plate gives the pump cylinder a proper angle for operation.
anti-seize compound	This is a grease-like mixture applied to the threads of metal nuts which prevents them from locking, or seizing, together so they can be separated in the future.
arrow keys	These keys are located on your computer keyboard. They are arrows that can move your computer cursor in any of four directions.
atmosphere	The air that surrounds you.
atmospheric pressure	The pressure that is present in the air, or atmosphere, around you. Normal atmospheric pressure is about 1 bar or 14.7 psi.
Autoclave speedbite fitting	A 1/8” tube fitting made by Autoclave, Inc. which is used for sealing high pressure fluids.
Autoclave speedbite fitting port	This is the port that the Autoclave Speedbite Fitting connects into.
Auto Op or automatic operation	A feature of PumpWorks software which allows for the pump system to be operated automatically.
auto ramping Operation	See Ramping Operations
Automatic Volume operation	Using PumpWorks software, the pump cylinder(s) will stop pumping after a specified amount of fluid has been pumped.
automatic time operation	Using the PumpWorks software, the pump cylinder(s) will stop pumping after a specified amount of time has passed.
auxiliary A/D channel	Quizix pump controllers and PumpWorks software have auxiliary, or spare A/D channels that can be connected to your pump system to display signals such as pressure and temperature.
auxiliary digital input signals	Quizix controllers and PumpWorks software have the capability of sensing and displaying user logic signals, such as from a contact opened or closed by a microswitch.

auxiliary valve cable	This connects the pump controller to the auxiliary pilot solenoid valve manifold.
auxiliary valves	The Quizix controller and PumpWorks software have the capability of operating additional valves that the user may add to the pump system.
auxiliary valve window	This PumpWorks software window controls any auxiliary valve(s) the user has added to the pump system.
back-drive	If the pump cylinder pressure is above a critical pressure (which varies from 1,000 to 5,000 psi depending on pump type) **and** power is lost to the motor driver, pressure forces on the piston are so strong that the ball screw will rotate as the piston is pushed backwards. The pump cylinder pressure will then drop until the pressure is reduced below the force necessary to back-drive the piston.
ball nut	The ball nut works with a ball screw to convert the rotary motion of the motor and harmonic drive into linear motion for the piston.
ball nut assembly	This includes the Ball nut, ball screw, and the mechanical parts which support the ball nut and ball screw, such as the flexure and ball nut flange.
ball screw	The ball screw has threads on which the ball nut turns. Together the ball nut and the ball screw convert the rotary motion of the motor and harmonic drive into linear motion for the piston.
ball screw pitch	The ball screw is machined with a specific number of threads per inch or pitch. The ball nut will advance this distance for each revolution of the ball screw. For example, if the ball screw has 8 threads per inch, then the ball screw will require 8 full rotations in order for the ball nut to advance one inch.
BAUD rate	This is the speed of the electrical communication signal used by the controller and the computer. For example is 28.8 kilobaud is twice as fast as 14.4 kilobaud.
bearings	Inside of the pump cylinder are radial bearings and thrust bearings which hold the ball screw in place, but allow it to rotate.
bidirectional	Capable of operating in two directions, or, to go back and forth.

cable clips	The metal clips mounted on an assembly (controller or driver) that lock around the end of the cable connector to keep the connector and attached cable firmly in place.
cable connection sensing	This is a controller and pumpworks software safety feature that detects the presence or absence of certain cables in a system.
cable extension	The cables supplied with the pump system can be extended with additional cable.
cable retainers	A metal clip on each side of the cable connector which allows the cable to be locked firmly in place with cable clips.
calibrate	To check or adjust a measuring instrument so it remains accurate.
cam rollers	A cam roller is located on each side of the pump cylinder and allows the user to view the position of the piston.
capillary viscometer	A tube that develops pressure drop proportional to flow.
cascade	The computer positions all open files so that only the top of each window is displayed.
ceramic	The pistons are made from ceramic, a material that is almost unscratchable and highly corrosion resistant, but is slightly brittle and breakable.
color coded	Each pump cylinder has a different color band which corresponds to the color used to display information about that pump cylinder in the pumpworks software.
communications port	The serial data cable from your controller plugs into the serial communications port connector on the back of your computer. It is sometimes referred to as a com port or comm port.
component	One part or piece of the pump system.
Com port	See communications port.
compression ring	The compression ring holds the safety rupture disk in place, inside of the safety rupture disk holder.
concave	The inside hollow of a curve, as in the inside of a bowl.
configuration	The particular arrangement of the parts that make up your pump system.

Constant Delta Pressure Mode	The system will pump fluid at a constant pressure differential across a core sample. To maintain this constant pressure differential the fluid delivery rate of the active pump cylinder will change, as needed.
Constant Pressure Mode	The fluid pressure for the active pump cylinder remains the same, at a user selected value. To accomplish this the fluid delivery rate of active pump cylinder will change, as needed.
Constant Rate Mode	The active pump cylinder's fluid pump rate remains constant at the user specified value. The active pump cylinder's fluid pressure is set by the system flow resistance. The system flow resistance is the degree of ease or difficulty at which fluid will pass through a system.
continuous flow pumping	The pump system can pump fluid for any length of time without stopping. This is accomplished by two pump cylinders working together for one fluid. One pump cylinder, the active cylinder, will pump, or deliver, the fluid while the other pump cylinder, the standby pump cylinder, fills and pre-pressurizes. Pulseless continuous flow is achieved by precisely coordinating the switching between the two cylinders.
controller fuse	An electrical safety device that protects the electric circuit going to the controller by melting when overloaded by a malfunction.
controller on/off switch	This on/off toggle switch allows power going to the controller to be turned on or off.
controller option switches	Four sets of eight individual on/off switches located on the back of the SC-2400 controller. These switches are preset by the manufacturer and set up the pump cylinder configurations.
controller serial number	Located on the rear panel. This tells you the version of the controller hardware you are using.
controller side panels	The metal side panels of the controller are available in three types; stand-mounted, rack-mounted or table.
controller status indicators	Four sets of eight each LED Indicators which show the SC-2400 controller is operating.
convex	The outside curve, as in the outside of a bowl.
corrosive fluids	Fluids or chemicals that gradually wear down or eat away at the pump system.

cup-type seals	A seal that looks like a "U" on cross-section.
current value	The value, or number, that is operating, or applies now.
cursor	A blinking element on your computer screen that shows the space where the next letter or number will appear.
cycled mode	Individual pump cylinder operating mode where only one cylinder is used to approximate the activity of a cylinder pair.
cylinder barrel	The round metal part that extends out from the pump housing where the user's fluid is held. The piston enters the cylinder barrel during fluid pumping.
cylinder barrel assembly	The cylinder barrel assembly consists of the cylinder barrel, cylinder seal, seal back-up rings and seal retaining nut.
cylinder barrel retaining ring	A ring that screws into the pump housing to keep the cylinder barrel in place.
cylinder barrel volume	The cylinder barrel volume consists of the dead volume and the piston stroke volume (the volume displaced by one piston stroke).
cylinder support block	Use pump cylinder support block
cylinder retaining fingers	Small metal pieces which hold the pump cylinder in the cylinder block on a stand-mounted pump system.
data log	This PumpWorks software feature allows you to automatically record data from your experiment onto a computer hard disk.
data log parameters	This is where you decide which data items you want recorded in your data log.
debug	A PumpWorks software option that provides access to the Quizix controller so the manufacturer will be able to assist you in resolving any problems that might occur.
deburr	To deburr is to remove any sharp edges or corners
default	The default option is a pre-set value chosen by PumpWorks when the user decides not to pick a different option.
default names	The name given to a pump cylinder, pilot solenoid valve, or auxiliary valve when a pump system is initially shipped from Quizix. The user can change the default names at any time.

default pressure unit	The unit of measure for the default pressure is PSI, or pounds per square inch.
default rate unit	The unit of measure for the default rate is in milliliters per minute.
deliver	To pump or push fluid from a pump cylinder into a user's experiment or sample.
deliver valve	This valve controls the flow of fluid from the pump cylinder to a user's experiment, or sample.
delta pressure	The measured amount of pressure, or force, across a section or portion of the system.
depressurize	To reduce the pressure on the fluid inside the cylinder barrel of a pump.
depressurizing	To reduce the pressure inside a cylinder barrel. This is accomplished by retracting the piston, thereby increasing the fluid volume inside the cylinder barrel.
destination	The place or point where the fluid is going.
dialog box	This is a window in the PumpWorks software that contains a form, or checklist, for you to fill out.
differential error	This is the measured rate at which the actual pressure is approaching the set-point pressure.
differential gain or differential servo gain	The amount by which you multiply the differential error to convert it to a rate of change for the pump cylinder so that the actual pressure is matched to the set-point.
digital overpressure	This controller software safety feature causes the cs to stop pumping if the user set safety pressure is exceeded.
digital underpressure	This controller software safety feature causes the pump cylinders to stop pumping if the pressure transducer voltage drops below a factory preset level.
display units and precisions	This PumpWorks software window allows you to choose the unit of measure to use when displaying pressure, rate and volume; and to specify the resolution, or number, of decimal places displayed.
driver	An abbreviation, or shorter name, for the motor driver.
driver air holes	These are located on the bottom of the driver and provide air intake for the driver fan.

driver fan	The driver fan is located at the end of the driver, next to the heat sinks, and keeps the driver cool during operation.
driver fuse	A safety device containing an element that protects the electric circuit going to the driver by melting when overloaded by a malfunction.
driver on/off switch	This on/off toggle switch allows power going to the driver to be turned on or off.
driver serial numbe r	Located on the rear panel of the driver, this will also tell you the driver version. If no driver version is stated, you have version 1.
driver side panels	The side panels of the driver are available in three options; side-mount, rack-mount or table.
dual motor driver	The dual motor driver provides the motor drive for two pump cylinders and relays status information to the pump controllers.
dust protection plug	A plastic cover used to protect parts from dust and dirt during shipping.
Dynamic Data Exchange (DDE)	A Windows software capability that allows multiple programs to share data in real time. This capability allows PumpWorks to send data, such as rates or pressures, to one or more programs while allowing another program to control pump operation.
emergency stop switch	This immediately shuts off all pulses to the dual motor driver and will cause a sudden stop of the pump cylinders. This is to be used in emergency only. It is located on the front panel of the SC-2400 controller.
end	A button on the computer keyboard which will take the cursor on the computer screen and move it to the end of the line you are working on.
error	An error is a fault that has happened somewhere in the pump system that requires the user to take action to resolve it before the pump system can be operated again.
error log	This PumpWorks software feature is a time record of the errors that have happened to a pump system.
errors present	This PumpWorks software message means that there is currently an error in the pump system that has not been acknowledged or resolved.

exit options	Some of the PumpWorks software windows have certain options which the user selects to exit that menu, i.e. “Exit, No Change” or “Yes, Accept Change”.
extend	The forward direction for the piston.
extended A/D values	PumpWorks can handle an additional 16 A/D channels if the user adds a special card to their computer.
extending	The action of the piston moving forward in the cylinder barrel which causes fluid to be delivered out of the pump to the user’s experiment.
execute	To begin.
fill	To load fluid into a cylinder barrel as the piston retracts.
fill valve	This is the valve that is between the pump cylinder and the supply of fluid. The fill valve controls the process of bringing the fluid into the pump cylinder.
flexspline	A circular, metal part that is part of the harmonic drive. The flexspline fits around the outside of the wave generator bearing,
flexure	A mechanical assembly used to equalize side forces on a ball nut assembly
flow rate	The user specified rate the pump cylinder operates at when operating in a Constant Rate Mode.
fluid inlet tubing	The tubing used to connect the fluid inlet tee to the “fill” side of each valve.
fluid outlet tubing	The tubing used to connect the flluid outlet tee to the “deliver” side of each valve.
fluid tight	No leaks occurring in the system. The fluid is contained within the pump system without escaping.
fluid tubing	The tubing which carries the fluid through different parts of the pump system.
fluid plumbing	This consists of fluid tubing, tees, ferrules and nuts.
fuse	An electrical safety device containing an element that protects an electric circuit by melting when overloaded by a malfunction.
fuse holder	A mechanical part that contains a replaceable fuse. It is located next to the power cord connector.

geared mode	A pumping mode that operates two pump cylinders so they move in equal, but opposite directions, at the user set rate. At the end of the piston stroke, both pump cylinders change direction simultaneously (at the same time) and continue to run at the set rate. This mode does not provide pulseless fluid flow.
governs	To control or dominate.
QD fitting or quick disconnect fitting	This quick disconnect plastic fittings, which are located on the pilot solenoids and the CV valves, are used to connect the air lines necessary to operate the valves.
guide rail roller surface	The top surface of the guide rail, where the cam rollers move, or roll, on the guide rail.
hard limit switch	A switch on the pump cylinder that stops the pump controller from moving the piston in either direction. This is a back-up safety feature that normally will not be activated.
harmonic drive	A gear mechanism which reduces the motor rotation speed. It is located inside the pump housing, near the motor.
harmonic drive adapter	A mechanical part that holds one half of the harmonic drive gear assembly.
harmonic drive assembly	This is the harmonic drive plus the motor housing adapter and harmonic drive adapter.
hastelloy	This is a metal alloy that is highly corrosion resistant.
HC	This is an abbreviation for hastelloy
heat sink	A metal part, with fins or ribs, that carries excess heat away from the heat source. The SC-220 dual motor driver and some pump motors use heat sinks.
hierarchy	Ranked according to importance.
holding extend	This Pumpworks software motion status message means that a pump cylinder is operating and the piston is extending at zero speed. When the rate becomes higher than zero (non-zero) the piston will extend.
holding retract	This Pumpworks software motion status message means a pump cylinder is operating, and the Piston is retracting at zero speed. When the rate becomes higher than zero (non-zero) the piston will retract.

home	A button on the computer keyboard which will take the cursor that is on the computer screen and move it to the beginning of the line you are working on.
host link	This is a data link which can be used to link the pump system computer with another computer. With such a link, a user can export system data to a second computer for real-time analysis while an experiment is running or use a second computer to control the pump operation.
host link communications protocol	The set of rules the user needs to follow to read data and set data over the host link.
Inactive Wash Area	This is wash Area that does not have the internal or external o-rings and therefore cannot be used to circulate fluid to rinse the piston.
independent cylinder operating mode	One pump cylinder operates by itself and is limited by the single stroke fluid volume. Independent cylinder operating modes are not capable of pulseless continuous fluid flow of more than one stroke volume.
independent constant delta pressure	One pump cylinder operates by itself to maintain a constant pressure differential across a portion of a fluid path by changing the fluid delivery rate as needed. Continuous operation is limited to a single stroke fluid volume.
independent constant pressure	One pump cylinder operates by itself to maintain constant fluid pressure at a user selected value. To accomplish this the fluid delivery rate of the pump cylinder will change as needed. Continuous operation is limited to a single stroke fluid volume.
independent constant pressure cycled	A single cylinder cycles between constant pressure operation and refilling. Continuous flow is approximated by automatically refilling after each stroke volume is used up.
independent constant rate cycled	A single cylinder cycles between delivering and refilling. Continuous flow is approximated by automatically refilling after each delivery stroke and then restarting fluid delivery.
independent constant rate operation	One pump cylinder operates by itself at a user specified constant rate. Fluid pressure will vary determined by fluid resistance in the fluid path. Continuous operation is limited to a single stroke fluid volume.
internal offsets	An automatic pressure transducer calibration feature used with recirculation systems. It is available for viewing only when in the recirculation mode.

interrupt request	A PumpWorks software communication method. An example is when the controller sends information to the PumpWorks about a pump cylinder, it first must request to interrupt the computer's current task.
kPa	This is an abbreviation for kilo pascals, which is a unit of measurement for pressure.
lag bolt	A type of bolt that is used to attach the top cover of a stand-mounted pump shipping box to the base of the box.
logging interval	Data will be taken at a user specified interval, or time span, and recorded in the PumpWorks software data log file.
lubricate	To apply a liquid to the surface to reduce friction.
main menu bar	This is the rectangular shaped bar that is horizontal across the top of the PumpWorks software main window and contains key words for the pull-down menus.
main window	This screen appears each time PumpWorks software is started. It displays information about each pump cylinder and allows for the user to read data and set operating parameters.
manifold	This supplies air to the Pilot Solenoids which actuate the CV valves.
max extend	See maximum extend.
maximum extend	The furthest, or maximum, that the piston can move during normal operation in the forward, or extend, direction.
maximum value	The highest number, or value, that can be entered.
max retract	See maximum retract.
maximum retract	The furthest, or maximum, that the Piston can move during normal operation in the backward, or retract, direction.
mechanical subcomponents	There are subcomponents, or smaller parts, that make up a mechanical assembly of the pump.
metal ferrules	Metal compression rings used to attach teflon tubing to air actuated valves in high temperature systems.
microswitches	Microswitches are used to detect the movement of the piston. There are two triggers, two soft limit switches and two hard limit switches, one each for the retract direction and one each for the extend direction.
minimum value	The lowest number, or value that can be entered.

modes	See Operating Modes
modular power cord connector	A modular power cord connector which allows electrical power from different countries to be plugged into the same device.
motion status	The motion status indicates what the piston is doing at any given time. The display field for motion status is located at the top of the main window below the “Cylinder” title.
motor adapter housing	A mechanical part on which is mounted the stepper motor and one half of the harmonic drive at the back of the pump cylinder.
motor assembly	This includes the stepper motor, motor cable, cable connector, motor adapter housing and associated parts.
motor cable	This cable is permanently attached to the motor and connects the motor to the motor driver.
motor driver	This provides power for the pump cylinder and relays status information to the pump controllers.
motor extension	A mechanical assembly which lengthens the distance between the motor and the pump housing in high temperature pump systems. This allows the Pump Housing to be heated inside of an oven while keeping the motor and harmonic gearing unheated outside of the oven.
motor extension cable	This cable, with a 9 pin DB type connector at each end, connects the dual motor driver to the motor. It is used when the driver needs to be at a greater distance from the pump cylinders.
motor resolution (in steps)	This is the number of steps the motor takes to complete one complete turn, or one revolution.
motor shaft	The portion of the motor that rotates.
motor shaft key	This part keeps the Harmonic Drive from turning when the motor shaft rotates.
not inst (not installed)	This message will appear in the motion status field when the controller cannot detect the presence of a pressure transducer, motor driver or pump cylinder. No pump cylinder actions can be taken through the PumpWorks software when a pump cylinder is detected as not installed.
num lock	A key on the computer keyboard which, when pressed, will allow you to use the numbers on your numeric keypad.

numeric keypad	This is located on the right hand side of your computer keyboard. It has numbers, arrows and cursor movement options.
offset	The electrical shift of a signal around the zero reading.
open-end wrench	This is a wrench with a "U" shaped, or open, end that is used to loosen or tighten bolts.
operating mode	This term refers to the way the pumps are operated. An operating mode is a particular configuration, or set-up, that allows the pump system to be operated in a specific pre-determined manner.
operating mode window	This PumpWorks software screen allows the user to select an operating mode and displays which operating mode is currently being used.
operating perameter setup window	This allows the user to change the default value of the return rate multiplier, the return rate minimum, the proportional servo gain and the differential servo gain.
paired constant delta pressure delivery	A pair of cylinders which work together to pump fluid at a constant pressure differential to a core sample. To maintain this constant pressure differential, the fluid delivery rate of the active pump cylinder will change, as needed.
paired constant delta pressure receive	A pair of pump cylinders which work together to extract fluid at a constant pressure differential from a core sample. To maintain this constant pressure differential, the fluid delivery rate of the active pump cylinder will change, as needed.
paired constant pressure bidirectional	A pair of cylinders maintains a constant pressure by either delivering or receiving fluid.
paired constant pressure delivery	The fluid pressure for the active pump cylinder remains the same, at a user selected value. To accomplish this the fluid delivery rate of the active pump cylinder will change, as needed.
paired constant pressure receive	The fluid pressure for the active pump cylinder remains the same, at a user selected value. To accomplish this the fluid delivery rate of the active pump cylinder will change, as needed.

paired constant rate delivery	A pair of pump cylinders delivers fluid at a constant rate by maintaining constant piston velocity. Pressure varies depending on flow resistance.
paired constant rate receive	A pair of pump cylinders receives fluid at a constant rate by maintaining constant piston velocity. Pressure varies depending on flow resistance.
paired cylinder operating mode	Paired modes use two pump cylinders which are automatically controlled to provide continuous pulse-free fluid flow. The active pump cylinder will be delivering or receiving fluid, while the standby pump cylinder will be refilling and pre-pressurizing. Switch-over to the standby pump cylinder is accomplished without introducing pressure pulses into the system to allow pulse-free continuous fluid flow operation.
paired geared mode constant rate operation	A mode that operates two pump cylinders so they move in equal, but opposite directions. At the end of the piston stroke, both pump cylinders change direction simultaneously (at the same time). Geared modes are not pulse-free.
parameters	The conditions the pump system is set to run within.
perpendicular	Crossing at a right angle, or 90 degrees.
Phillips-head screw	This screw head has two lines on its head which cross each other at 90 degrees.
Phillips screwdriver	A screwdriver designed to tighten or loosen Phillips-head screws.
pilot solenoid	An electrically operated air solenoid which controls air flow and is used to open or shut the fluid paths in the CV valves.
pilot solenoid manifold	This part takes in air from the air supply and distributes it to the pilot solenoids.
pilot solenoid assembly	The pilot solenoids, pilot solenoid manifold, and air tubing and fittings.
piston	A cylindrical rod used to displace fluid in the cylinder barrel.
piston carriage	This is a metal part with a cut out area to support the piston inside of the pump cylinder
piston nut	A hexagonal (six sided) metal nut, that is part of the piston holder. The piston nut is used when extracting the piston from they cylinder barrel.

piston position display	A bar graph in the PumpWorks software that shows how far the Piston is inserted inside of the Cylinder Barrel.
piston removal tool	This tool, supplied with your system, is inserted into the pump housing to engage the piston nut during piston removal or replacement. This is a 27 mm socket welded on an extension tube.
piston stroke	The length of travel that the piston can move, either retracting or extending.
piston stroke volume	The volume displaced by a one stroke of the piston.
pneumatically actuated	pneumatically actuated, or air actuated, means the operation is begun by a force of air.
pneumatic valve	A valve which is operated by the force of air.
positive displacement pumps	A pump where a solid object is used to physically displace the pump fluid.
power connector assembly	The power connector assembly includes a receptacle for the power cord, a fuse holder and a voltage selector in one unit.
pre-pressurize	The process of the standby pump cylinder building up pressure to match the pressure in the active pump cylinder, then staying ready until it is needed. Because the standby pump matches the pressure of the active pump, pressure pulses are avoided during continuous operation.
pressure	A measurement of the magnitude of a force. This can be measured in different units, which include PSI, bar or pascals.
pressure pulse	A change in pressure which lasts a short duration.
pressure transducer	A device that measures fluid pressure and converts it to an electrical signal. This signal is sent to the pump controller for conversion and display as a number.
pressure transducer cable	The cable that goes from the pressure transducer to the controller.
pressure transducer calibration	The process of checking and adjusting a pressure transducer so that its readings are accurate.
pressure units	Units of measure for pressure which include PSI, bar and pascals.

pressurizing	The process of increasing pressure on a fluid. This is accomplished in a pump by extending the Piston, which reduces the volume available to the fluid thereby increasing the pressure.
printed circuit board or PC Board (PCB)	A group of electrical components on a flat board. There are three types of boards included in an SC-2400 controller; rear panel board, Main PC Board and DSSIP Board.
programmed	A set of instructions that allow the computer to operate the pump system.
prompt line	The prompt line is located in the bottom border of the active window of the PumpWorks software and gives you instructions relating to the task at hand.
proportional error	The proportional error is multiplied by a constant (the Proportional Gain) to generate a rate. This rate will change the pump pressure to the set-point value.
proportional gain or proportional servo gain	The proportional gain is a user set constant which is multiplied by the proportional error which generates a corrected rate for maintaining constant pressure. This rate will change the pump pressure to the set-point value.
PSI	This stands for *pounds per square inch* which is a measure of pressure.
pull down menu	When you click on a word in the PumpWorks software menu, a list of choices appear, this is called a pull down menu.
pump body assembly	The pump housing, plus all of the internal components. These include the motor assembly and ball screw/ball nut assembly.
pump controller	The pump controller is an electrical subsystem which directs all pump operations. The pump controller communicates to the user through the PumpWorks software.
pump cylinder	A mechanical assembly that allows fluid to be pumped.
pump cylinder support block	A metal part with a cut out area which supports a pump cylinder on stand-mounted pump systems
pump housing	The main mechanical body which covers, or houses, the working parts of the pump cylinder.
quizix.erl	The name of a computer file which contains a listing of errors that have happened in the pump system.

quartz transducer	An extremely accurate and stable pressure transducer which can be used to calibrate a typical pressure transducer.
query	A question presented by the computer that requires you to answer or make a choice.
quit option	A feature in the DOS version of PumpWorks which allows you to exit the PumpWorks software.
ramping operation	Using the PumpWorks software, the pump system can change gradually from one flow rate or pressure to another over a user determined period of time.
rate scalers	A PumpWorks software feature that adjusts the fluid rate or fluid volume to account for either expansion or contraction of the fluid as it is heating up or cooling down.
rate units	This is a unit of measure for rate. It is stated in either milliliters per minute or milliliters per hour.
recirculating	To run through the pump system more than once.
recirculating mode	A special pump operating mode where fluid is continuously pumped from a pump cylinder, through a sample and back into another pump cylinder without the fluid being depressurized and without pressure pulses.
recirculating parameters	This PumpWorks software window is where you set your parameters for recirculating mode.
reconfigure	To configure the system again, or to give the computer a new set of instructions to change the operation of the pump system.
reed switches	The switch used to provide piston position information. Reed switches are located on the sensor board of the pump cylinder.
reset recirculating mode	This is the only way to properly exit from recirculating operation.
reset volumes	The display volume for any pump cylinder can be set to zero, at any time, using this button.
residue	A deposit that remains on a surface after fluid has been removed.
retaining fingers	A mechanical part which holds a pump cylinder into the cylinder support block on a pump stand.
restore	Brings a window that is minimized, into full view again.

retract	The direction the piston moves when it backs out of the cylinder block.
retracting	The motion of the piston, as it pulls back out of the cylinder barrel to fill with fluid.
return rate multiplier	The return rate multiplier is the number that is used to multiply the set rate to determine the return rate. This number is always 1 or greater, so that the return rate is equal to or faster than the set rate. A faster return rate is used in a pair of cylinders so the returning (stand-by) cylinder has enough time to prepressurize.
return rate minimum	The lowest rate or speed that the standby pump cylinder will retract at.
RS-232 cable	The cable that connects the Pump controller to the computer and carries the serial data communications.
run conditions	The various text messages that are displayed in the motion status field when the pump cylinder is operating.
rupture	A breaking or opening.
safety pressure	This is the pressure which, if exceeded, the pump cylinders will stop pumping. Quizix pumps have three built-in safety pressure systems: digital safety pressure, the analog safety pressure and the safety rupture disk pressure.
safety rupture disk	A metal disk that is installed in a safety rupture disk assembly.
safety rupture disk assembly	This includes the safety burst disk holder, the safety rupture disk, compression ring, locking fitting and relief fluid exit. One is installed on each pump cylinder to burst in the case of overpressure, caused by a malfunction.
safety rupture disk exhaust port	Located on the safety burst disk assembly, this port should be connected by the user to a dump location in case of ruptured disk activation and fluid release.
safety rupture disk holder	The metal enclosure that holds the safety rupture disk.
schematic	A drawing of electrical or fluid connections.
scroll	The main window of the PumpWorks software has a left and right arrow in a bar along the bottom of the window. This allows you to move, or scroll, left or right to view all of the pump cylinders.

seal assembly	This includes the seal, seal back-up ring, and the seal retaining nut.
seal extraction rod	A tool, supplied with your tool kit, that is used to extract a seal without damaging the pump cylinder.
seal insertion guide ring	This ring guides the seal and the seal insertion plunger into the pump cylinder during seal installation.
seal insertion plunger	A tool, supplied with your tool kit, that is used to push a seal out of the seal guide ring and into the cylinder barrel.
seal retaining nut	This is a threaded nut, used to keep the seal, and seal back-up ring inside of the cylinder barrel.
seal support ring	This is a cylindrical ring which sits inside the cylinder barrel and is used to support high temperature seals.
sensor board	This board keeps track of where the piston is and sends that information to the dual motor driver. The sensor board is located under the right side cover of the pump cylinder.
sensor cable	This connects the pump cylinder sensor board to the dual motor driver.
sequencer	A programming language available in the PumpWorks software to set up and automatically control complex pump operations.
serial expander/isolator	An interface device which allows up to four Quizix pump units to operate from one computer communication port.
serial port or serial communications port	The serial data cable from your controller plugs into this slot on the back of your computer. It is also called the Com Port or the Communications Port.
servo	A servo operates to keep a selected parameter constant by changing one or more other parameters.
servo extend	The piston is in the process of extending in order to achieve the desired pressure.
servo retract	The Piston is in the process of retracting in order to achieve the desired pressure.
set direction	This is used in independent operating mode to instruct a specific pump cylinder to either extract or retract.
set pressure	The field where the user sets the pressure that the pump will pump at when operating in constant pressure or constant delta pressure mode.

set flow rate	The user sets the rate the pump flows at when operating in a Constant Rate mode.
side covers	The plastic or aluminum part that covers the side rails of the pump cylinders
side rails	These are located under the left and right side covers of the pump cylinders and keep the ball nut from spinning freely when under load, or pressure.
slope	at an angle
soft limit switch	This switch is located on the sensor board. When activated, this switch quickly stops the piston from moving any further in the direction it had been moving. However, the piston is able to move in the opposite direction.
software	A computer program which, in this case, operates the pump system.
software version	This is a number which indicates which version, or code number, of the PumpWorks software you are using. It is viewed from the menu item titled “software versions”. It also tells you the code number of the software in the controller.
software zero offset range	Range of values that the user may input to change the zero point setting on a pressure transducer.
solvent	This is a petroleum based product used for cleaning.
speedbite fittings	See Autoclave speedbite fitting
speedbite plug protectors	A plastic insert used to protect speedbite fittings, or ports, during shipping.
speedbite plugs	A solid metal piece that completely seals a fluid port.
speedbite tubing port	A fluid port designed to fit an Autoclave Speedbite Fitting.
SS	This is an abbreviation for stainless steel.
stainless steel	This is a type of steel which is mostly resistant to corrosion.
standby pump cylinder	When two pump cylinders are being operated in a continuous flow delivery mode, the cylinder that is filling with fluid and pre-pressurizing is the standby pump cylinder. The deliver valve of the standby pump cylinder is always closed.
standby time	The time it takes for the standby pump cylinder to fill and pre-pressurize.

status bar	This is the horizontal bar that is on the bottom of the main window in PumpWorks software and provides messages regarding the status, or condition of the controller(s), data logging, sequencer and error messages.
steady state	constant or unchanging
stepper motor	The motor attached to the pump cylinder which rotates in the direction and at the speed dictated by the controller.
stopped conditions	Text messages in the motion status to tell you if the piston is in Max Extend or Max Retract, or if it is stopped in between these two points.
stroke volume	The amount of fluid the pump cylinder is capable of pumping during one piston stroke.
symmetrical	Something that is the same on both sides.
system level integration	The user's entire experiment is controlled by the Quizix PumpWorks software.
T-type seals	A type of seal that is shaped like a sideways "T" and is usually made of an elastomer.
tab key	Press the Tab key on your computer keyboard to move from one box to the next.
teflon	A unique polymer with excellent anti-friction and anti-corrosion properties.
tiled	The computer positions the open files so all that are open, two or more, are entirely in view at the same time.
tilt angle	The 0 to 15 degree angle, that the pump cylinders are positioned at.
time formats	There are three options for recording time, the actual time and date as set on your computer, elapsed time or cumulative time.
titles	PumpWorks software allows you to provide your own column headings, or titles, for you Data Log.
torque	A turning or twisting force.
torque wrench	A wrench that has a gauge built into it which allows the user to tighten nuts and bolts to a specified degree of force, or torque.

transducer assembly	The transducer assembly includes the transducer, transducer cable and fluid tubing.
transducer cable	This cable connects the pump controller to the pressure transducers.
transducer calibration	See calibrate
trapped gas	Gas that cannot be easily expelled or removed from the pump system.
trigger switch	This switch on the sensor board is sensed by the PumpWorks software to automatically tell the controller that the Piston has reached the end of its stroke.
tubing	!/8" and 1/4" tubing is used to connect the pump cylinders, valves and Pressure Transducers in the pump system.
unacknowledged	Not yet corrected.
unidirectional	Moving or operating in one direction only.
uninterruptible power supply (UPS)	A source of power that will continue if the main power source stops or has a surge of power.
unresolved	Still exists, not yet solved or corrected.
vacuum grease	A type of grease used to lubricate the CV valves.
valve	An air-actuated valve manufactured by Vindum Engineering that controls the flow of fluid.
valve assembly	A collection of CV valves, tubing, air lines and pilot solenoids.
valve cable	This cable connects the pump controller to the pilot solenoids.
valve cable extension	This is an extension that can be added to the valve cable to allow the pilot solenoids to be located a longer distance from the controller.
voltage setting	The power your system is set to run on, either 110 to 120, or 215 to 240 volts. This must match the electric supply for your country.
volume	A measured quantity or capacity, usually measured in milliliters or liters.
voltage setting	This is the voltage range the equipment is set to operate on. This must match the electric supply that your country operates on, either 110 to 120 or 215 to 240 volts.

wash area	An optional feature used to wash corrosive fluids off of the piston as it retracts.
wave generator bearing	This is part of the harmonic drive and is located inside of the motor adapter housing,

INDEX

A

Air Connections Diagram 8-4
Air Supply 8-3
  Checking 12-17
  Connection 12-17
  Problems 12-10
  Requirements 2-11, 12-17
Air Tubing 3-2

B

Ball Nut 7-4
  Assembly 7-4
Ball Screw 7-4
  Re-greasing 11-11
Bearing 7-5

C

Cable 9-1
  Connections 6-3
  Connections Sensing 5-1
  Data Link 3-2, 6-3, 9-2
  Extensions 9-3
  Front Panel 6-4, 9-3
  Labeling 5-1
  Motor 3-2, 6-3, 9-1
  Power 9-2
  RS-232 6-4
  RS–232 9-2
  Sensor 3-2, 6-3, 9-1
  Transducer and Valve 6-3, 9-1
  User Interface 6-4, 9-3
  Verification 3-1
Calibration 11-24
  Calibrated Gauge 11-22
  Calibrated Gauge Method 11-22
  Calibrated Pressure Source 11-24
  Calibrated Pressure Source Method .. 11-24
  Methods 11-21
  Setup Diagram 11-22
Cam Roller
  (Picture) 11-10
  Replacing 11-9
CMD-5000 ..... 1-4, 6-1, 11-18
  High Temperature 2-9
  Subcomponent 6-1
Communication Errors
  See Errors 12-3
Conditions
  Extending 4-5
  Hold Extend 4-6
  Hold Return 4-6
  Max Extend 4-5
  Max Retract 4-5
  Retracting 4-5
  Run 4-5
  Stopped 4-5
  Stopping 4-5
Connection Checklist 3-2
Controller
  See CMD-5000 1-4
Corrosive Fluids 7-7, 8-8
Current System Status Window 12-1
Cylinder Barrel 7-4, 7-5
  Removing 11-3
  Replacing 11-9
  Seals
    Changing 11-3
Cylinder Switch Status Window 12-2

D

Dialog Boxes 4-4
Digital
  Overpressure 5-1
  Underpressure 5-2

E

Emergency Stop 5-5
Error Code
  See Two Digit Display 12-8
Error Log 12-1
Error Messages 12-2
Error State Capture Mode 12-2
Errors
  Analog Overpressure 12-9
  Communication 12-3, 12-9
    Buffer Overrun 12-5
    Cannot be Established 12-4
    CRC Check 12-5
    Input Error 12-5

No Response from Pump 12-5
Digital Overpressure 12-9
Digital Underpressure 12-9
Driver Cable 12-9
Driver Power 12-9
Driver Status 12-9
Emergency Stop 12-9
Fan Does Not Run 12-11
Immediate 12-3
Logged 12-3
Low Side Driver 12-9
Motion 12-9
Motor Runs, No Motion Detected .12-14
Motor Stall 12-15
No Fluid Is Being Delivered 12-13
Piston Movement 12-14, 12-15
Present 4-19
Pressure 12-16
Sensor Cable 12-9
Soft Limit 12-10
Soft Limit Warning 12-3
Transducer Cable 12-9
Two Digit Display Error Code 12-8
Valve Cable 12-10
Extending 4-5

F
Fan
Error 12-11
Maintenance 11-17
Flow Rate 4-10
Changing A Set Flow Rate 4-10
Changing Multiple Flow Rates 4-10
Changing Single Flow Rate 4-10
Fluid Flow Diagram 4-18
Fluid Flow Direction 4-11
Bi-directional 4-11
Delivery 4-11
Receive 4-11
Fluid Inlet 3-3
Fluid Leak 12-11, 12-12
Finding Your Leak 12-13
Leak Testing 12-12
Leakage Basics 12-11
Fluid Outlets 3-3
Fluid Plumbing 8-5
Fuse
Holder 6-2
Replacing 10-3

H
Harmonic Drive 7-4
Re-greasing 11-13
Hastelloy 7-7, 8-8
High Temperature
Cables 2-9
CMD–5000 Dual Controller Driver .. 2-9
Pump Cylinders 2-8
Setting Up 2-8
Stand Mounted 2-9
Transducers 2-9
Valves 2-9
Hold Extend 4-6
Hold Return 4-6

I
Immediate Error 12-3

L
Liquid
Filling Your Pump System With 3-4
Low Pressure Operation 7-3

M
Maintenance 11-1
Max Extend 4-5
Max Retract 4-5
Menu Bar 4-3
Motor Driver
Subcomponent 6-2
Motor Housing 11-14
Motor, Stepper 7-4

O
On/Off Switch 6-2
Operating Modes 4-10
Choosing 4-11
Independent
Constant Delta Pressure 4-14
Constant Pressure 4-13

Constant Pressure Cycled 4-13
Constant Rate (IND CR) 4-13
Constant Rate Cycled 4-13
Paired
Geared Mode Constant Rate 4-14
Unidirectional Capillary Viscometer 4-14
Overview 1-1

P

Paired
Constant Delta Pressure Delivery 4-15
Constant Delta Pressure Receive 4-15
Constant Pressure Bidirectional Half Rate 4-16
Constant Pressure Delivery 4-15
Constant Pressure Receive 4-15
Constant Rate Delivery 4-15
Constant Rate Receive 4-15
Geared Mode Constant Rate Without Valves 4-14
Pilot Solenoid 8-2, 8-8
Check 12-17
Piston 7-4, 11-8
Cleaning 11-8
Inspecting 11-8
Installing 2-1
Movement Error 12-14
Position Field 4-4
Position Indicators, Physical 12-2
Re–installing 11-9
Plumbing 1-4, 8-1
(Picture) 8-6
Connection Verification 3-1
Power 10-1
Basic Requirements 10-1
Changing the Voltage Setting 10-2
Considerations 2-10
Cord 6-2
Cord Receptacle 6-4
Pressure
Current 4-9
Error 12-16
Is Not Constant 12-16
Overshoots Setting 12-16
Problems 12-15
Set 4-9
Changing a Set Pressure 4-9
Changing Multiple Set Pressures 4-9
Pressure Transducer 1-4, 8-1, 8-4, 8-8, 11-21
Calibrating 11-20
Check 3-5
Error 12-15
What is a Pressure Transducer 11-21
Pump
Name 4-4
Number 6-4
Operating Basics 4-1
Safety Features 5-1
Pump Controller
Diagnostics 6-6, 12-6
See also CMD-5000 12-6
Software 6-7
Initialization 12-8
Pump Cylinder 5-4, 7-1
5000 Series Models 1-2
6000 Series Models 1-2
Base Plate 7-7
C-5000 1-3
C-5000 Ambient Temperature 2-2
Components 1-2
Configurations 4-10
Direction 4-18
High Temperature 8-8
High Temperature Option 7-7
Independent Configuration 4-16
Maintaining 11-9
Mixed Configurations 4-17
Mixed Modes 4-17
Number 4-4
Operating Modes 4-11
Orientation 7-4
Overhead View 11-12
Paired Configuration 4-17
Sensor Board 7-6
Starting 4-7
Independent Operating Modes 4-7
Paired Operating Modes 4-8
Stopping 4-8
Stroke Volume 4-17

Subcomponents 7-4
Volume 4-10
Pump Data & Controls Window 4-3
Pump System
Checkout 3-1
Setup 2-1
SP–5200 Front View 2-4
SP-5200 Picture 1-3
Stand Mounted
Setting Up 2-6
SP-5400 2-5
Unpacking 2-1
PumpWorks 1-4
Dialog Boxes 4-4
Introduction 4-1
Main Pump Data/Controls Window ..4-4
Main Window 4-1
Menu Bar 4-3
Pump Data/Controls Window 4-3
Status Bar 4-3
Title Bar 4-2

R
Recirculating 4-16
Reset Recirculating Mode 4-16
Retracting 4-5
Rollers 7-5
Run Conditions
See Conditions 4-5

S
Safety Features 5-1
Safety Pressure, Set 4-19
Safety Rupture Disk 5-2, 8-7
Holder 5-4
Ratings 5-3, 11-19
Replacing 11-18
Seal Assembly 7-5
Seals
Changing 11-4
Cup-Type 11-4
Seal Insertion Procedure 11-6
Cup-Type (Picture) 11-5
Removal Procedure 11-5
Seal Insertion Tools 11-6
T-Type 11-4
T–Type
Seal Insertion Procedure 11-7
T-Type (Picture) 11-5
Serial Expander/Isolator 6-6
Side Rails 7-5
Software Updates 12-18
Spare Parts Kit 11-1, 11-3
Status Bar 4-3
Stopped Conditions
See Conditions
Stopping 4-5
Support Stand 1-4

T
Title Bar 4-2
Tools 11-1
Special Tool Kit 11-2
Troubleshooting 12-1
Basics 12-1
Situations 12-10
Tubing 8-5
Components (Picture) 8-7
Cylinder to Pressure Transducer 8-6
Cylinder to Valve 8-5
Fluid 3-2
Inlet Tee to Valve 8-5
Outlet Tee to Valve 8-5
Two Digit Display 6-4, 12-6
Error Code 12-8
Error Messages 12-5
Does Not Complete
Initial Check 12-6
Does Not Light 12-6

U
Uninterruptable Power Supply 10-1
Ratings 10-2

V
Valve 1-4, 8-1, 8-8, 11-25
Cable Connection Check 12-17
Check 3-3
Clogged (Obstructed) 12-17
Fill and Deliver 4-18

Leaks 12-18
Problems 12-16
Volume
Cumulative 4-10

W
Warning
Soft Limit 12-3
Wash Ring 7-9
Diagram 7-9
Spare Parts Kit 7-10
Wave Generator Bearing 11-15
Windows 4-2
Menu Bar 4-3
PumpWorks Main Window 4-2
Set Cylinder # Operating Mode 4-12
Status Bar 4-3

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